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MINUTES OF PROCEEDINGS

OF THE

INSTITUTION

OF

CIVIL ENGINEERS;

WITH

ABSTRACTS OF THE DISCUSSIONS.

VOL. XXI.

SESSION 1861-62.

EDITED BY

CHARLES MANBY, F.R.S., M. INST. C.E., HONORARY SECRETARY;

AND

JAMES FORREST, ASSOC. INST. C.E., SECRETARY.

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ERRATA.

Page 148, line 27, *for* Joseph Maudsley, *read* Joseph Maudslay.

„ 160, line 3, *for* June 30, 1861, and June 29, 1862, *read* June 30, 1860, and June 29, 1861.

INSTITUTION

OF

CIVIL ENGINEERS.

SESSION 1861-62.

November 12, 1861.

GEORGE PARKER BIDDER, President, in the Chair.

At the commencement of the proceedings, Mr. Bidder,—President,—thus addressed the Meeting:—

Gentlemen,

On the first Meeting of each of the Sessions during which I have had the honour to fill this Chair, it has been my singularly painful duty to notice the loss of some old and distinguished member of the profession. On the first occasion on which I addressed you as President, I alluded to the departure from amongst us of Mr. Brunel, and of my lamented friend Mr. Robert Stephenson;[1] on the next, to the death of Mr. Locke;[2] and now the melancholy task devolves upon me of adverting to the decease of Sir William Cubitt, a past President of this Institution, and one of the oldest of its Members. During his long connection with our Society he did much to advance its interests. He zealously assisted in its early struggles, and, as a Vice-President and as a President, lent effectual aid in extricating it from its financial difficulties. In his professional career he was early distinguished for his knowledge of mechanical engineering, and in that branch he introduced some ingenious improvements. Among his principal Civil Engineering works may be mentioned the South Eastern and the Great Northern Railways; the gigantic floating landing stages at Liverpool; the iron bridge at Rochester; and his efficient superintendence of the construction of the Crystal Palace in Hyde Park in 1851, which service was recognized by her Majesty, who conferred on him the honour of knighthood. Sir William, unlike our other Members to whom I have referred, attained an advanced age. During his long career he secured the respect and esteem of all his professional brethren, as well as the consideration of all with whom he was brought into contact. His success was doubtless, in a great degree, to be ascribed to the soundness of his early mechanical experience, a fact which he never failed to impress upon all the younger Members of the profession. His loss will be sincerely felt by our Society, of which he has been so useful a member. His son, Mr. Joseph Cubitt, has succeeded his father in the Council. Let us hope that Sir William's memory may be kept alive amongst us by the works of his son.

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[1] *Vide* Minutes of Proceedings Inst. C.E, vol. xix., p. 214.

[2] *Ibid* vol. xx., p. 1 *et seq.*

No. 1,047.—"The Hooghly and the Mutla." By James Atkinson Longridge, M. Inst. C.E.[1]

During the discussion of the Paper on Indian Railways, which was brought before the Institution in the Session of 1859-60, by Mr. James John Berkley, M. Inst. C.E., the subject of the proposed establishment of a new port at the head of the Mutla, as an auxiliary to the present port of Calcutta, was briefly alluded to by the Author of the present Paper. The few remarks he then made led to the expression of a wish, on the part of the President, that he would "present a Paper to the Institution, embodying the results of his experience as to the local circumstances connected with the navigation of the Hooghly and the Mutla."[2] The magnitude of the subject, and the paucity of accurate observations on the hydrological features of the two rivers, have rendered the compliance with the wish thus expressed a somewhat difficult task; and although, in consequence, the Paper is not so complete as the Author could have desired, yet he has considered it his duty to present it to the Institution, in the hope that a profitable discussion may arise, on an interesting and important branch of professional practice.

The Author deems it desirable to divide the Paper into the following heads:—First, a statement of the commercial importance of the Port of Calcutta. Secondly, a brief account of the present mode of transport of the traffic to the port, and the modification of it, by works now in progress. Thirdly, a sketch of the physical features of the two outlets, the Hooghly and the Mutla. And, Fourthly, remarks on the past and present state of those rivers, as navigable channels.

The port of Calcutta is the emporium of the commerce of a great part of the peninsula of Hindoostan. Situated on the Hooghly, it communicates by inland navigation with the valley of the Ganges, which river, in a course of 1,500 miles, traverses Bengal and the North-western Provinces, until it reaches the confines of the Punjaub; while its confluent, the Brahmapootra, extending to the north-eastward, maintains an additional communication with the fertile districts of Silhet and Assam. An analysis of the official returns of the port of Calcutta, during the five years ending the 30th of April, 1861, gives an annual average of 979 vessels, importing 626,798 tons; and, for the same period, an annual average of 1,033 vessels, exporting 619,674 tons. These figures, however, can only be considered as an approximation to the total trade of the port. The amount of tonnage paying toll on the Eastern Canals was in 1856 about 1,700,000 tons, and in 1859 it was not less than 2,250,000 tons. This traffic is wholly dependent on water communication, and is conducted, under circumstances of great difficulty and danger, at considerable expense. The Author refrains from expressing any opinion on the policy of the late East India Company, or in reference to the extent which, under their rule, European enterprise might advantageously have been permitted directly to aid in the development of the productions of the country, and the facilities of its internal communications; but under present circumstances it may safely be asserted that, great as is the present trade of Eastern India, it might be considerably increased, if a wise policy should encourage, and allow full scope to, the capital and energy of Great Britain.

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[1] The discussion upon this Paper extended over portions of two evenings, but an abstract of the whole is given consecutively.

[2] *Vide* Minutes of Proceedings Inst. C.E., vol. xix., pp. 620 and 623.

For about four months of the year, during the flood season, about one-third of the whole traffic to Calcutta enters the Hooghly from the Ganges by means of the three rivers, the Bhagiruttee, the Jellinghy, and the Matabanga. These rivers are generally designated the Nuddea rivers. They are in effect flood outlets of the Ganges, having their heads at Sooty, Jellinghy, and Sadaspore respectively. They run in a southerly direction, and by their union form the river Hooghly, about 45 miles above Calcutta. (Plate I. Sketch map of the Delta of the Ganges and of the Bay of Bengal.) During the dry season, from November to July, the Nuddea rivers are no longer navigable; and then the traffic descends the Ganges to the point where it meets the stream of traffic from the Brahmapootra. It afterwards proceeds, viâ Dacca, through the Sunderbunds navigation, to the head of the Mutla, whence, by the Biddiadhurree river, it reaches the Eastern Canal, and by means of it, the Circular Canal and Tolly's Canal, finally enters the Hooghly at Calcutta. (Plate I. Plan of the Hooghly and the Mutla.) The delays and obstructions in these navigations have frequently been brought under the notice of Government, and on the 15th February, 1853, Mr. Mactier, the deputy-collector of Furreedpore, reported on the subject as follows:—" In my tours through the district, during the last and the present years, my attention was called by certain opulent merchants to the loss they sustained by delays and obstructions in the navigation of the various water-routes to Calcutta; and during my recent visit to that city, I did my best, while *en route*, to ascertain the cause of these delays and obstructions, and whether they could be remedied. My remarks refer to what is called the inner route, through the Sunderbunds, navigable for boats up to 1,000 maunds (about 38 tons). By this route an immense number of boats, carrying perishable cargoes, such as fruit, fish partially cured and alive, &c., proceed, and the delay of even a few hours in the arrival of such cargoes causes great loss; with cargoes of a less perishable nature, such as grain, oil, &c., time is a matter of consequence, as the quicker they arrive, the more voyages will the carriers be able to make, and the delay of a day may cost the merchants dear, as they lose what they call the bazaar, *i. e.*, what was dear one day falls greatly in price the next; however, as this is a matter of such obvious importance, it will be sufficient merely to call attention thereto."

Mr. Mactier then states, that the delays arise, first, from the want of towing-paths, and secondly, and principally, from the want of room in the canal between the salt-water lake and the Hooghly. In illustration he continues:—"At some short distance from the Dhappa toll-house, all the various passages through the Sunderbunds unite, and though there is difficulty in getting along, still it is practicable to move; but, after passing the toll-house the press commences; all along the northern side of the Balliaghatta Canal is a line of boats, sometimes double, unloading their cargoes into the warehouses on the northern bank; and at low water, although there is plenty of water in the canal, it is almost impossible for any but the smallest boat to move. In the Circular Canal it is clearer, but at about a quarter of a mile on the canal side of the lock leading to the Hooghly the crush, 'bedaud,' as the natives call it, again commences. To show the results of my own experience, I may state, that in going to Calcutta, my own boat, of about 250 maunds (9 tons), was detained from 5 A.M. to 3 P.M. in going from the Dhappa toll to the Hooghly, a distance of about 4 miles; and it was only by using my own influence with the boatmen of the various boats 'luggaoed' to the bank, that I got along at all. On my return I was from 1 P.M. to 1 A.M. in accomplishing the same distance, while the manjees of some large pulwars, who effected their deliverance from captivity at the same time, said it had taken them four days."[1]

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[1] *Vide* "Selections from the Records of the Bengal Government," No xix pp. 54, 55.

These evils were in full force in 1857, when the Author, having frequently to pass through the canal, was sometimes four hours in reaching Dhappa, a distance of 2½ miles, in a small row boat, which, moreover, was in great danger of being crushed, owing to the large cargo boats coming to a deadlock. Upon one occasion he found the ordinary traffic suspended for an entire day, in order to permit of the passage of the Government opium boats. One of these stuck fast, in passing the Bulliaghatta Bridge, and a further delay of a tide, throughout the whole navigation, was the necessary consequence. So crowded is this part of the navigation, that it is no uncommon occurrence for the boats, about the time of high water, to become so closely wedged together that accidents occur, of such a serious character as frequently to result in the loss of many boats and cargoes. The average rate at which goods could be conveyed by this system of navigation is about 15 miles per day, a rate so slow, that it involves a serious loss of interest upon the capital of the merchant, owing to the time occupied in the transit of opium, indigo, and other merchandise of a valuable character.

In 1857 the Author instituted a careful inquiry as to the actual cost of transport of merchandise to Calcutta; and he considers that the figures given in the following table may be taken as close approximations to the actual rates:—

Character of Merchandise, and where from.	Distance carried.	Rate per Ton per Mile.		
		For Transport.	Insurance & Interest.	Total.
	Miles.	d.	d.	d.
Rice from Dacca	267	0·371	0·140	0·511
Jute do.	267	0·404	0·388	0·792
Rice from Buckergunge . .	270	0·423	0·206	0·629
Average	268	0·400	0·244	0·644

It may be interesting to examine, how far the railways in the district, when completed, will be able to compete with the inland navigation. For this purpose the Author selects the East Indian Railway, intercepting the Ganges traffic at Rajmahal, and the Eastern Bengal Railway meeting it at Kooshtee. The relative cost of carriage to Calcutta, he assumes, will be as follows:—

	Distance.	Rate.	Total Cost.
	Miles.	d.	s. d.
From Rajmahal *viâ* the Nuddea Rivers. . .	300	0·644	16 1
„ *viâ* the Sunderbunds . . .	529	0·644	28 4
„ By East Indian Railway . .	200	1·125	18 9
From Kooshtee *viâ* Nuddea Rivers. . . .	247	0·644	13 3
„ *viâ* Sundberbunds	377	0·644	20 3
„ By Eastern Bengal Railway .	110	1·125	10 4

Hence, taking the proportion of traffic passing by the Nuddea rivers, at about one-third of the whole, the average cost of carriage per ton would probably be:—

	By Water.		By Rail.	
	s.	*d.*	*s.*	*d.*
Rajmahal to Calcutta . . .	24	3	18	9
Kooshtee to Calcutta . . .	17	11	10	4

Thus showing, on the ordinary traffic, a saving of 20 per cent. and 40 per cent. respectively, in favour of the rail, exclusive of the advantages of a safe and speedy transit of hours, instead of weeks, which, in the case of the more valuable class of goods, will further enhance the benefit derived from the railway communication.

There can be but little doubt that the Hooghly was formerly one of the principal mouths of the Ganges, but at present it communicates with that great river only by the three Nuddea rivers. The positions of the exits of these rivers from the Ganges are subject to great variation, owing to the soft nature of the banks rendering them unable to resist the action of the waters in the flood season. It will be unnecessary to enter into the details of these changes; but some idea may be formed of their extent, when it is stated that between 1824 and 1852, the head of the Bhagiruttee was shifted 14 miles to the south-eastward, and that during the same period, the Ganges shifted that part of its course many miles. The depth of water at the exits of the rivers from the Ganges varies with the time of the year, and also from one year to another; and sometimes, as in 1853, the three rivers are almost closed. The following are the results of a series of observations of the maximum and minimum depths from 1840 to 1853, inclusive:—

	Bhagiruttee.		Jellinghy.		Matabanga.	
	Ft.	In.	Ft.	In.	Ft.	In.
Least depth in dry season .	3	9	5	0	1	8
	to		to		to	
	0	0	0	0	0	0
Greatest depth in rainy season	32	3	30	0	27	0
	to		to		to	
	12	0	18	10	17	6

The quantity of water from the Ganges discharged by these rivers varies greatly. It has been stated by Major Lang, the former superintendent, that in a high flood, it amounted to 200,000 cubic feet per second, whilst in the month of March, it did not exceed 5,000 cubic feet per second, of which a large portion was derived from filtration.

The Bhagiruttee and Jellinghy unite at Nuddea, about 75 miles above Calcutta; and they are joined at Chogdah, about 23 miles lower down, by the Matabanga, from whence the united rivers form the Hooghly. At Calcutta the Hooghly is about 800 yards wide, and from thence downwards its width increases gradually to about 1,800 yards at the lower part of Fulta Reach. It is there joined on the right bank by the Damoodah River, which formerly flowed into the Hooghly at Naiserai, about 35 miles above Calcutta. After leaving the hills it runs for many miles of its course through spreading plains, above the level of which, as is usual with such rivers, it gradually raises its bed. In the year 1763, notwithstanding the natives had previously constructed embankments along the side of its elevated channel, the Damoodah burst its banks at Selimabad, and rushing down in a southerly direction excavated for itself its present outlet, which, entering the Hooghly at right angles, effected, as will hereafter be noticed, a serious deterioration in the navigable channel of that river. The Damoodah runs through a course of about 320 miles, and drains an extent of about 7,000 square miles. In the dry season its supply of fresh water is inconsiderable, but during floods it discharges into the Hooghly a vast volume of water, highly charged with silt. Its maximum flood discharge, measured about 20 miles above Burdwan, is nearly 600,000 cubic feet per second; but at Omptah, about 75 miles lower down, the channel is so small, as to be incapable of passing more than 76,000 cubic feet per second. The difference flows over the right bank, and flooding the intervening country, finds its exit eventually by the Roopnarain, another river which joins the Hooghly about 5 miles below the outlet of the Damoodah. The Roopnarain has a course of nearly 230 miles, and a drainage area of about 500 square miles. Its characteristic features are much the same as those of the Damoodah. At the junction of the Roopnarain, the Hooghly makes an acute-angled bend to the eastward, for a distance of about 9 miles, to Diamond Harbour. Here it bends again to the south-west for about 10 miles to Culpee, at which place its high-water bed attains a width of 2¾ miles. Below Culpee the estuary assumes a south-westerly direction, and rapidly widens. On the right bank, at about 10 miles below Culpee, it is entered by a comparatively small river, the Huldea, opposite to which on the left bank is Channel Creek, which forms the north-east boundary of Saugor Island, and is the route by which the steamers from Calcutta, being unable to pass through the eastern canals, enter the Sunderbunds on their way to the Ganges. The high-water width of the estuary at this point is 6½ miles. From thence it still pursues a southerly direction, and the distance between its shores continues increasing until, at Saugor Island, its width is about 17 miles. Below Saugor Island are the sea channels of the estuary, which are greatly encumbered with sandbanks. At the southern extremities of the sands, called the Sandheads, vessels receive and discharge the river pilots, and taking the lower floating light as the limit of the river navigation, the total distance from the sea to Calcutta is about 140 miles.

Having given the preceding general description of the river, the Author will now lay before the Institution such details as he considers essential to the formation of an opinion as to the state of its navigable channel; his information being chiefly derived from the printed reports of a Committee appointed by Government in 1853, to inquire into the state of the river; consisting of—Captain Divie Robertson, officiating Superintendent of Marine; H. Piddington, Esq., and T. T. Mackenzie, Esq. These gentlemen were directed to ascertain "the state of the River Hooghly, particularly whether it has deteriorated for purposes of navigation, what has been the nature and progress of the deterioration, to what causes it is owing, whether it is likely to continue, and if so, whether any approximate guess can be formed as to the period at which ships of large burthen may be expected to resort by preference to the Mutla, supposing the head of that river to be connected with Calcutta either by a railway or a ship canal."[1] The Committee sat for forty-nine days, and examined twenty-six witnesses, of whom seventeen were pilots, four commanders of steam-tugs, two commanders of river-steamers, and three Government officials. These witnesses on some points differed materially; but this is not surprising, as the Committee state that, "The periodical surveys of the river, up to a comparatively recent period, were taken by the primitive mode of sailing a number of pilot-vessels in line through the several channels, sounding, as they went, the existence of new obstacles, or of changes in the old banks being ascertained by the grounding of the vessels on them."[2]

The first channel entered by inward-bound vessels is called the Eastern Channel, and is situated between the Saugor Sand and the Eastern Sea Reef. It has a low-water depth of from 3½ fathoms to 6 fathoms, but it has a middle ground at its northern end. Some of the witnesses state, that within their experience, the tails of the sands have extended nearly 6 miles to the southward. Proceeding upwards, the Gaspar Channel to the east, and the Thornhill Channel to the west, running parallel to each other, and leading up to Saugor Roads, are the next in order. It is stated, that in 1781, the Gaspar Channel had 4¼ fathoms in it at low water. About the beginning of the present century it became closed, and was only again buoyed off towards the end of 1817. Previously to its reopening, although the lower end remained filled up, there was a depth of 17 feet, or 18 feet at the upper end. In 1836 there was a depth of 3 fathoms in it, and in 1852 a depth of 2¾ fathoms. The Thornhill Channel has also closed and reopened during the present century. It was first discovered in 1806, and had then a bar at the lower end, which had from 2¼ fathoms, to 2¾ fathoms, upon it. This channel also closed in 1819, or 1820. It again opened out, and was buoyed off in 1837, having then 20 feet on the lower bar. In 1844 the channel had nothing less than 3 fathoms in it, but in 1854 the depth on the southern bar was only from 2¼ fathoms, to 2⅝ fathoms. Saugor Roads is a good channel, with abundance of water and room for the purposes of navigation, but within the memory of the senior pilots, the soundings at its upper end have decreased not less than 2 fathoms. Lloyd's Channel is the next in order, and leads up to the Cowcolly, or lower Kedgeree Roads. It was first discovered and buoyed off in 1816. It had then from 11 feet, to 12 feet, at the lower entrance, and 3½ fathoms up to its head. The depth of water in it has since fluctuated exceedingly. At present it is 11 feet, or 12 feet, deep throughout, but it is gradually shoaling. Cowcolly Roads is a channel with deep water; but it has, however, shoaled considerably as well as narrowed. At Kedgeree Green, where formerly there was commodious anchorage for large ships, only small vessels can now go in. The amount of shoaling within the experience of the present pilots is stated to be about 2 fathoms. After leaving Lloyd's Channel, the deep water keeps along the western shore up to the entrance of the Auckland Channel, which, together with its continuation, Mud Point Channel, bears over to the eastern shore. These two last-named channels have varied considerably in their condition. From 1843 to 1848 the Auckland Channel was reported to be in a bad state. It then improved, and for the three years preceding 1853, was stationary. Since 1848 the Auckland and Mud Point channels have been in a better condition than ever previously known to the witnesses. Above the Mud Point Channel are the inner and outer Rangafullah channels. The inner channel formerly ran close to the Culpee shore, and was in use up to 1847 from the earliest period to which the evidence before the Committee reached. It was a good channel, but narrow; it began to fill up at Middle Point about 1834, or 1835, and closed about 1847. It afterwards re-opened, and then finally closed as it at present remains. The outer channel is a better and a wider channel than the inner. It closed, however, about 1845; but has again opened, and is now in use. It is subject to great and rapid changes, and has a middle ground with only 13 feet, or 14 feet, of water upon it, which is constantly shifting. In 1853 the worst part of the channel was only from 10 feet, to 11 feet, deep, and throughout there was no anchorage. In 1836 an island sprang up on the west side of the channel, but it began to waste away in 1840, and had disappeared altogether in 1842. The next channel in succession is Culpee Roads. This has not been subject to any great variation; its present depth averages about 5½ fathoms.

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[1] "Reports and Proceedings and Appendix of the Committee appointed by Government to Inquire into the State of the River Hooghly." Calcutta, 1854, p. 1.
[2] *Ibid.*

About 2¼ miles above Culpee, the river narrows to a width of about 1½ mile, and then turns round in a westerly direction. On the concave side of this bend is Diamond Harbour, where, in former days, the ships of the East India Company loaded and unloaded their cargoes. It is distant in a direct line about 32 miles from Calcutta, with which place it has, at various times, been proposed to connect it by means of a railway or ship canal. At present, it is almost unused as a harbour. Four of the witnesses examined, stated that it had shoaled considerably, but the majority were of opinion that no change of importance had taken place. Between Diamond Harbour, and Hooghly Point, the safe navigation of the river is impeded by what are called the Kookerehatty Lumps. These are formations of hard sand, which at times are very troublesome, and especially so in the months of September and October, owing to their shifting about in the Channel, from side to side, under the influence of the periodical freshes and strong flood tides. The navigation of this part of the river, in consequence, requires constant care. The lumps, however, can be avoided, as there is always a channel to be found on one, or the other side of them. There does not appear to have been any material change in the average capacity, or physical condition of this portion of the river during the last forty years. Above the lumps is the Hooghly Sand, running east and west. The channel round the south side of it is deep and good up to the mouth of the Roopnarain. It is generally believed that the Hooghly Sand has remained unchanged, with the exception of a trifling extension, upwards, or downwards, when exposed during the rainy season, to the alternating action of the river freshes and strong flood tides. There is a channel at the north side of the Hooghly Sand, frequently used by vessels of light draft. This channel opens and closes periodically, in accordance with the condition of the James and Mary Reach immediately above it, opening with the western gut, or channel of that reach, and closing when the eastern gut is opened out. The character of this channel, when open, does not seem to have varied. At the commencement of the James and Mary Reach, the River Roopnarain joins the Hooghly, nearly at right angles. Between this point and the outlet of the Damoodah River, where this reach terminates, the bed of the Hooghly is much obstructed by banks and other formations of sand. Both these affluents have much the character of mountain torrents: during the dry season the volume of water from them is comparatively small; but during the sudden freshes caused by the rains, their waters, heavily charged with earthy matter, rush down, and materially affect the character of the channels of the James and Mary Reach, and thereby render it the most dangerous portion of the navigation. The James and Mary Sand occupies the lower portion of this reach, having on the two sides of it the guts, or channels, to which reference has just been made.

As a rule, these channels never have a navigable depth at the same time. Some of the witnesses speak to one, or two years within their experience, when they were open together, but with an insufficient depth in each. The eastern gut is opened by the freshes of the wet season, when the flood tides are weak, at which time the united waters of the Damoodah and Hooghly, direct the force of the strong ebb-tides, down the left bank of the latter river. The free flow of the water being impeded by the rush of water below from the Roopnarain, almost at right angles, an eddy is formed, the silt is deposited, and the western gut is filled up. On the other hand, the western gut is reopened by the strong flood tides of the south-west monsoon during the action of which the Mukreeputty Lumps, joining on to the Hooghly Sand, form a bar across, and close the south entrance of the eastern gut. The western gut is subject to continual fluctuations as to the position of the deepest water, and both channels show important differences in soundings, at similar periods, in different years.

To the north of the James and Mary Bank there is only one channel up to Fulta Point; but as far as Nynan Point it is narrowed by the Nynan Lumps, which are very troublesome from their sudden and unexpected changes. Above Nynan Point the channel is broad and deep. Although the channels of the James and Mary Reach have always been considered as among the worst and most dangerous in the river, there were great differences of opinion between the witnesses as to their present, as compared with their former condition. Fifteen of them considered, that, on an average of seven years, there was no change for the worse, and eight were of a contrary opinion. From Fulta Point to Calcutta, the river consists of a series of curved reaches, with deep but narrow channels on the concave bends. In this division of the river there appears no evidence of any permanent deterioration. Periodical changes take place; the navigation being generally worst in September, October, and November, during the subsidence of the freshes, and shortly after their termination, the principal obstruction in the way of vessels ascending, being the shelves on the convex side of the channel, called respectively Fulta Sand, Royapore Sand, and Moyapore Flat.

In forming a summary of the preceding details, the river may be divided into three sections:—First, from Calcutta to Fulta House, a distance of about 34 miles, with an average high-water width of 1,300 yards; it consists of a series of deep but narrow channels, separated by bars at the points of inflection of the curved reaches. In this part of the river the navigation, though tedious and troublesome, is not dangerous; and though subject to periodical changes, the depth of water does not appear to have suffered any permanent diminution. Secondly, from Fulta House to Culpee, a distance of 24 miles, in which the high-water width widens out from 1 mile to 2¾ miles. This section embraces the junction of the Damoodah and Roopnarain rivers on the right bank, and the dangerous James and Mary Reach. The Channels in it are subject to great and sudden changes, the tides and eddies are strong, and sands shifting. There appears to be evidence of some permanent decrease in its depth, though not yet to such an extent as to have a serious effect on the navigation. Thirdly, from Culpee to the Sand Heads, a distance of 37 miles, in which the river widens out from 2¾ miles at Culpee to 17 miles at Saugor Point. This section contains many dangerous places, and the evidence goes to show, that there has been a decided and serious shoaling of the water in the channels, and that a prolongation seawards of the tails of the sands has taken place, to an extent of not less than six miles, within the last fifty years.

The information which the Author has been enabled to obtain in reference to the tidal phenomena of the Hooghly, is extremely scanty. The only tidal register which appears to have been kept, is that of the times and heights of high water and low water at Kidderpore Dockyard near Calcutta. The Author has made an analysis of the observations recorded in it during the twelve-months, from the 1st of July, 1843, to the 30th of June, 1844, from which he arrives at the following results:—First, that the duration of the flood was three hours during the freshes of the rainy season, and four hours during the dry season; and that the ebb lasted from eight hours to nine hours. Secondly, that the mean rise of tide, on an average of three days, commencing with each quarter of the moon, was, during the dry season, from October to February, both inclusive, at spring tides, 11 ft. 1½ in.; at neap tides, 7 ft. 0 in.; and from April to August, both inclusive; at spring tides, 12 ft. 2 in.; and at neap tides, 7 ft. 5 in. Thirdly, that during the north-east monsoon, from the middle of September to the middle of March, the night tides were higher than the day tides; whilst from the middle of March to the middle of September, when the north-west monsoon prevailed, the day tides were higher than the night tides; the maximum differences between the day and night tides, being severally, in the month of December, 1 ft. 10 in., and in the month of June, 1 ft. 2 in. Thus, it appears, that the variation of the tidal range at Kidderpore, between the dry season and the freshes is comparatively small, not exceeding 1 foot at springs, and 5 inches at neaps. This is somewhat remarkable, as, according to the season, the actual level of the surface of high water varies from 20 ft. 10 in. to 12 ft. 10 in. above datum, and that of low water from 7 ft. 6 in. to 3 ft. 0 in. It might be expected, that the volume of fresh water pouring down from the Nuddea River, the Damoodah, and the Roopnarain, would so far drive back the tidal flow as to prevent the rise at Calcutta; but such is not the case, the range being actually greater during the freshes, than during the dry season. The increased range in the wet season is probably due to the action of the monsoons. The south-west monsoons, assisting the tidal flow during the season of the freshes, and the north-east monsoon keeping it back during the dry season. At the Sand Heads, the rise of tide at springs is said to be 9 feet at the lower floating light, and from 12 feet, to 14 feet, at the upper floating light, but the Author is not aware that these measurements have been determined in a trustworthy manner. It is high water at full and change, at the Sand Heads at 9h. 0m., and at Kidderpore at 2h. 30m., thus giving the mean velocity of the tidal wave between these places as 26¼ miles per hour. The following Table shows the comparative velocity of the tidal wave, as compiled from the best information which the Author has been enabled to obtain:—

VELOCITY OF THE TIDAL WAVE IN THE HOOGHLY.

PLACES.	Distance between in Miles.	Velocity in Miles per Hour.	PLACES.	Distance between in Miles.	Velocity in Miles per Hour.
Lower Floating Light .			Entrance of Roopnarain		
Cowcolly	66	44	Kirnalpore	9¼	8½
Silver Creek	13	26	Moyapore	11	22
Culpee	9	18	Budge Budge . . .	5¼	21
Diamond Harbour . .	8½	17	Akra	5½	22
Entrance of Roopnarain	8½	17	Fort William . . .	9	18

The tidal streams in the sea channels leading to the river set round the compass thus: The first quarter flood runs W.N.W., round by north, to E.N.E. at last Quarter; the first quarter ebb runs E.S.E., round by south, to W.S.W. at last quarter. The maximum velocities of the flood and ebb streams are attained at the directions of N.N.W. and S.S.E. respectively, and they vary from 2 knots, to 3 knots, at springs, to, from 1 knot, to 1½ knot, at neaps. In the river the tidal streams vary in strength in different parts of the channel, and in accordance with the different seasons. In some places and at certain times, the velocity of the tidal stream is as much as 7 miles, or 8 miles an hour, whilst on the other hand, during the freshes, the ships at Calcutta will sometimes scarcely swing at their moorings. In the dry season, the upward tidal stream can be observed as far as Culna, about 56 miles above Calcutta. Above Culna, the current is constantly downwards, although there is a slight tidal rise perceptible at Nuddea, 78 miles above Calcutta.

The Hooghly is supposed to discharge about one-sixth of the waters of the Ganges; but from the small amount of existing information, it is impossible to make more than a rough approximation to the total quantity which it receives. During the dry season it is comparatively insignificant, being derived principally from filtration for several months of the year. Major Lang, when superintendent of the Nuddea Rivers, estimated the supply which they conveyed from the Ganges as about 200,000 cubic feet per second in August, and as not exceeding 5,000 cubic feet per second in March, a considerable portion of the latter quantity being derived from filtration. The Author assumes, that the actual quantity directly discharged from the Ganges into the Hooghly, varies from 200,000 cubic feet per second to 2,000 cubic feet per second; and that the variation in this quantity, corresponding to any given period of the year, is some function of the corresponding height of the Ganges. He further assumes that the velocity of the stream, issuing from the Ganges, will be as the square root of the head of water, and that the area of the exit channel, owing to the form of the banks, will be nearly as the depth, and consequently, that the discharge will be, nearly as the depth, multiplied by the square root of the depth; or, in other words, the supply from the Nuddea Rivers will be, as the square root of the cube of the depth of water, in the portion of the Ganges adjacent to their exit channels. From the data furnished by Major Rennell in his account of that river, the Author has prepared a diagram (Plate 1, fig. 1) showing the rise of the Ganges throughout the year at Jellinghy; and from this it appears that the average height and the discharge, as calculated on the preceding hypothesis, for each month in the year, would be as shown in the following Table:—

TABLE showing the estimated DISCHARGE from the GANGES into the NUDDEA RIVERS during the YEAR.

Month.	Rise of Ganges above lowest level in Feet.	Cubic Feet of Water per Second.	Total Cubic Feet in the Month.
January....	3	7,600	20,355,840,000
February...	2	3,700	8,951,040,000
March	1	2,000	5,356,800,000
April	0¼	2,000	5.184,000.000
May	3	6,760	18,105,984,000
June	11	46,100	119,491,200,000
July	22	130,000	348,192,000,000
August	29	200,000	535,680,000,000
September ..	23	144,000	273,248,000,000
October....	14	68,100	181,998,040,000
November ..	8	29,900	77,500,800,000
December ..	4	14,000	37,497,600,000
Cubic Feet discharged Annually			163,561,304,000

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[1] *Vide* Appendix to Memoir of A Map of Hindoostan. By James Rennell, F.R.S. London, 1793. Page 351, *et seq.*

It may therefore be estimated, that the quantity of fresh water passing into the Hooghly from the Ganges, through the Nuddea rivers, is upwards of 60,000 millions of cubic yards per annum; and as, in the absence of more complete information, it has been stated to the Author, that the amount brought down by the Damoodah and Roopnarain rivers is at least equal to that from the Nuddea rivers, he assumes, that the fresh water passing down the lower channels of the Hooghly is upwards of 120,000 millions of cubic yards per annum. Could this amount of water be conveyed to sea, as a limpid stream of uniform volume, it might perhaps exercise some beneficial influence on the channels through which it ran. The fact however is, that the greatest quantity of it passes down during the inundations, when the rivers of Bengal are highly charged with sediment. In considering its effects, it therefore becomes of importance, to form some estimate of the quantity of solid matter with which this water is charged.

From experiments made, in 1842, by Mr. Piddington, at Calcutta, it was ascertained, that the amount of silt held in suspension in the waters of the Hooghly, at noon on the first day of each month—supposing the silt to be measured when dried to the consistency of a sun-dried brick—was as follows:—

In January,	1 part in	3,519	In July,	1 part in	1,687
„ February,	„	2,717	„ August,	„	1,494
„ March,	„	857	„ September	„	1,672
„ April,	„	695	„ October,	„	5,087
„ May,	„	964	„ November,	„	1,910
„ June,	„	615	„ December,	„	2,443

Applying these results to the average monthly discharge of the Nuddea Rivers, as estimated in the calculated table (page 14), the amount of solid matter which they bring down in each month would be:—

	Cubic Feet.		Cubic Feet.
In January,	5,781,710	In July,	206,337,818
„ February,	3,294,456	„ August,	358,554,217
„ March,	6,250,642	„ September,	163,425,837
„ April,	7,458,992	„ October,	35,777,086
„ May,	18,782,141	„ November,	40,576,335
„ June,	194,294,634	„ December,	11,255,668

Hence the Author calculates, that not less than 39,000,000 cubic yards of solid matter are carried down each year, into the river and the sea channels of the Hooghly below Calcutta, and an equal quantity from the Damoodah and Roopnarain rivers, so that 78,000,000 cubic yards of solid earth are probably deposited yearly in the Hooghly and its estuary. How much of this is deposited seaward of Saugor Island it is impossible to say; but the existence of so large a mass of silt in the water makes it easy to account for the observed seaward prolongation of the tails of the sands, and also for the shoaling of the lower reaches of the river, where, owing to the greater width, the current is slackened, and deposit takes place.

It may be argued, that the data, upon which the preceding calculations are based, are insufficient to warrant the results which the Author has deduced from them; and it may further be said, that the observations of the amount of silt, held in suspension at Calcutta, do not afford the means of judging, whether any of that silt is carried down to the sea channels of the river, inasmuch, as if the land water were perfectly limpid, there would, at all times, be mud held in suspension in the tideway at Calcutta, from the constant disturbance of the shores and bottom of the channel, which the flood and ebb streams occasion. But to these objections the Author would reply, that in each twenty-four hours the quantity of water passing Calcutta downwards, exceeds the quantity passing upwards, by the amount of fresh water received from the Nuddea Rivers, and that this excess is carried seaward, charged with silt to the extent determined by Mr. Piddington's experiments. The only conditions under which this water, or the earthy matter which it contains, could return, would be, that the flood stream had such an increased velocity above the ebb, as would enable it to hold this extra matter in suspension. But this assumption will not bear examination, for it is during the freshes, that by far the greater proportion of the land water passes down, and then, as already noticed, the flood tide is so feeble, that often the ships at Calcutta will scarcely swing to the stream. To show, that the Author's estimate of the amount of solid matter conveyed to the sea, by the Hooghly, is not exaggerated, he may mention, that it is stated, that in the year 1792 one of the mouths of Bhagiruttee was filled up, by the deposit from the Ganges, to the level of the adjacent country, in the course of a week, although its channel was 5 miles long, and must have contained 900 millions of cubic feet. Major Rennell estimated that in the flood season the Ganges, from whence its waters are derived, contains one-fourth part mud in its water, and, on the authority of Captain Sherwill, it is stated, that the annual deposit in the Bay of Bengal, from the Ganges and the Brahmapootra, amounted to 1,500 millions of cubic yards.

The delta of the Ganges, is considered by Major Rennell, to commence at the exit of the Nuddea Rivers, a distance of about 220 miles from the sea, in a direct line, but 300 miles, reckoned by the windings of the river. Its lower part is a labyrinth of tidal creeks, and its coast line extends from 180 miles to 200 miles. The average fall of the delta, taking the shortest distance to the sea, is said to be about 9 inches per mile; and the surface fall of the Ganges in dry seasons, measuring along its course, is about 4 inches per mile. The stream of the Ganges varies in velocity from 3 miles per hour in the dry season, to 5 miles per hour, or 6 miles per hour in the rainy season; and in particular situations and circumstances it attains a velocity of 7 miles per hours, or 8 miles per hour. The soil of the delta of the Ganges consists of loamy sand and black mud.[1] It is unable to resist the action of the stream, and hence the course of the river is subject to great variations, and its banks are perpetually changing.

Below Calcutta the lands adjoining the Hooghly are on an average about a foot below the level of low water spring tides, but immediately adjacent to the river the banks are in many places several feet higher than the general surface of the country. This is also a characteristic feature of the principal Sunderbund creeks, evidently pointing to their origin, and to their having once served as outlets to the silt-charged flood-waters of the Ganges, which, in like manner, when passing down these creeks, as their volume swelled above the level of their beds, slackened their velocity at the sides of the widened stream, and deposited their earthy burthen in the eddies formed along the adjacent foreshores, thus gradually raising them above the level of the neighbouring lands, a process which, frequently repeated, eventually ended in diminishing the capacity of their channels, and successively disqualified each outlet for the office it had originally performed. On the sea-coast of the Delta there are eight openings, each of which has in turn probably served as the chief mouth of the Ganges. Of these the Hooghly is the most westerly, and the Mutla—the third from the west—is about 40 miles to the eastward of the Hooghly.

The Mutla is a tidal inlet of the sea rather than a river, inasmuch as it is not subject to floods, and, the fresh water entering, it is entirely confined to a small portion, which drains off the adjoining lands during the wet season. The principal rivers, or rather tidal creeks, with which it communicates are the Biddiadhurree and the Attara Banka at its head, the Edoo Creek and the Hoogledee about eleven miles lower down, and the Barnchoppy and Biddah Rivers at Cattalee. The two first-named form part of the inland navigation for country boats through the Sunderbunds to Calcutta, while the two last are in the route of the steamers which descend the Hooghly to Channel Creek, and which pass eastward by these creeks through the Sunderbunds to the Ganges, and, excepting the short period when the Nuddea rivers are open, the whole of the traffic to Calcutta from the Ganges passes across the Mutla.

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[1] In 1814 a boring was made near the Hooghly at Calcutta, in search of fresh water. This boring was carried through sands and clays to a depth of 140 feet, when it was left off in coarse grey sand, but no water was found.

The banks of the Mutla are low, and in this respect, as well as in the nature of the soil through which it passes, it may be said to be almost identical in its features with the Hooghly. But there are no bars or shifting sands in its channel, and it is free from the bore, which at times is so destructive in the Hooghly. It has a considerable depth, varying in different localities from 4 fathoms to 27 fathoms; and Lieutenant Ward, I.N., who surveyed it in 1853, reported on this point as follows:—"The least water in the channel I find to be 4 fathoms at low-water spring tides; there is therefore nothing to prevent vessels of the largest tonnage proceeding up the river at all times."[1] In the previous part of his Report he says:—"I find that no material changes have taken place in the river since surveyed in 1839. In the upper part, or that portion from the Manik Khaul to the Attara Banka, there appears to be no alteration; from the Manik Khaul to the sea does not appear to have been so minutely surveyed, in consequence there appears a difference in the surveys; the banks at the Sand Heads remain the same, with the exception that the bar formerly existing in the Eastern Channel has apparently been washed away. The banks at the Sand Heads are formed of a very fine sand, of a greyish colour; in the channels the bottom is a stiff blue mud, affording good anchoring ground: the banks in the river are also of sand, but with a coating of very soft mud. It is high water on the full and change at the Sand Heads at 9 hours, and at the head of the river at 11 hours 45 minutes. The rise and fall at Sand Heads 10 feet, at mouth of the river it is 12 feet; and at the head of the river it is 14½ feet. The tides run with a velocity of 4¼ miles per hour during the springs, and of about 2 miles per hour on the neaps."

The entrance to the Mutla is easy of access, and in the Sailing Instructions published by order of the Government, it is stated, that a stranger with Ward's chart could, with attention, conduct his ship in safety without a pilot, up to Cattalee, where there is excellent and safe anchorage. Its sea entrance channel lies between the Roymutla and the Bangadoony Sands. The total distance from the tail of these sands to the head of the Mutla at Attara Banka is 93 miles, and from the same point to the lower end of Bulcherry Island, where the channel of the estuary becomes confined between its high-water margins, 27 miles; a distance which may be favourably contrasted with the corresponding distances on the Hooghly, namely, that of the tail of the eastern sea-reef from the south end of Saugor Island, which is 50 miles. Passing upwards from Bulcherry Island, the channel of the Mutla runs nearly north, in almost a straight line, for a distance of 25 miles up to Cattalee Reach. Here it bends in a westerly direction for 5¾ miles, thus resembling in a remarkable manner the form of the Hooghly, from Diamond Harbour to the Roopnarain. At the end of this reach it again assumes a northerly direction for nearly 18 miles to the junction of the Hoogledee Creek, where it again turns westward for about 3 miles, and finally takes a north-easterly course to the head of the river, where it joins the Biddiadhurree Creek leading to Calcutta, and the Attara Banka, leading westward through the Sunderbunds. At the head of the river, where it is proposed to establish the new port, there is space for two hundred and forty ships, and in the Edoo Creek, for six hundred ships of the largest size, still leaving ample room for other vessels to swing in the stream.

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[1] *Vide* "Report of C. V. Ward, Lieut.-Commanding H. Co.'s S.V. 'Krishna.'" Selections from the Records of the Bengal Government, No. xix. p. 107.

The Author will now compare the two rivers, the Hooghly and the Mutla, in regard to their facilities for navigation, and their general hydrological features. In the Hooghly the river navigation extends from Calcutta, to Middleton Point at the lower end of Saugor Island, a distance of 99 miles, while the distance from the head of the Mutla to the river entrance at the south end of Bulcherry Island is only 65 miles, thus showing a gain of 34 miles, or about one-third, in favour of the Mutla.

Next, as to the depth of water:—By referring to the sections of the two rivers (Plate I.), if a standard of 24 feet at low water be assumed, it will be seen, that in the Mutla there are no shoals; whereas in the Hooghly there are six, of a length, in the aggregate, of upwards of 14 miles, and with a low-water depth upon them of from 15 feet to 18 feet only. To give a standard depth of 30 feet at low water, the Mutla would require deepening, at four places, to an extent varying from zero to 6 feet; whilst in the Hooghly the length to be deepened would be nearly 26 miles, and the depth to be excavated would be from zero to 15 feet. Again, in the Hooghly, the lowermost shoal is 63 miles from the uppermost, whereas, in the Mutla, taking even the 30 feet standard, the shoals, which are much less in extent, are all contained within a distance of 30 miles; or, if the first and the last, which are inconsiderable and might easily be removed, be neglected, then the only existing shoal would be comprised in a distance of 3¼ miles. It is further obvious, that the one shoal in the Mutla would be of little consequence, as compared with the six shoals in the Hooghly, separated as they are by intervals of miles from each other. In the former case, a vessel with the aid of steam might choose the time of tide, and having passed over the shoal, proceed to sea without further obstruction; whereas in the Hooghly, a vessel can only pass one, or two shoals in each tide, and she must then anchor, while waiting for the tide again to carry her over the next shoal, and so on, until she has succeeded in reaching the sea.

As an instance of the delay attendant upon the navigation of the Hooghly, the Author will refer to his experience, as a passenger down the river, in the Peninsula and Oriental steamer 'Bentinck.' She was drawing 19 feet 2 inches only, and left Garden Reach, Calcutta, at 6 h. 0 m. A.M. on the 9th of April, 1857. The moon being at the full, the tides, spring tides; and the weather fine throughout the passage. On arriving at Ootabarea Reach, she was obliged to anchor for two hours, waiting for water over the Moyapore Sand. At 10 h. 15 m. A.M., she started again; at 1 h. 30 m. P.M., she passed the James and Mary Shoal, and at 2 h. 45 m. P.M., anchored again at Culpee, where, as the navigation of the Hooghly could only be carried on by daylight, she remained until 8 h. 45 m. A.M., on the 10th. She then proceeded on her downward voyage, and in consequence of there not being sufficient water through the Gaspar Channel, anchored in Saugor Roads, at 2 h. 25 m. P.M. on the morning of the 11th. She left Saugor Roads, and the pilot quitted the ship at 11 h. 40 m. A.M. Thus fifty-four hours were occupied in reaching the sea, notwithstanding the favourable conditions under which the passage was made. Similar delays, not only occasion a great loss of time and money, but, also involve serious risks; as it often happens, that vessels cannot anchor with safety, in the places where they are required to wait, for the tide to carry them over the succeeding shoals. Outward-bound vessels have frequently been delayed in the Hooghly, for two, or three weeks, from these causes; and in contrasting the capabilities of the two rivers, it may be stated generally, that whereas, a ship drawing 24 feet could only get to sea from Calcutta, by the aid of steam, and under the most favourable circumstances, in from three to four days, or during the south-west monsoon in five days, the same vessel could at all times get to sea from the head of the Mutla, in from eight hours, to ten hours. By the adoption of the Mutla, it is believed, that two days could be saved, in the time of the postal and passenger service, between this country and Calcutta. In the Author's Report on the Calcutta and South Eastern Railway (1857), he entered fully into the comparative charges of the two ports, and the result showed a saving of £587. 10*s.* on each voyage of a ship of 1,000 tons, in favour of the Mutla, or about 11*s.* 9*d.* a ton.

With regard to the more prominent points involved in the comparison of the two rivers, it has already been noticed, that they both run through a precisely similar country; that both are remarkably alike in their courses, and that both are subject to the same tides; yet, that one is dangerous and difficult, whilst the other is safe and convenient for navigation. Whence does this difference arise?—The physical distinctions are, that in the Hooghly there is a vast, though greatly varying, supply of fresh water, acting simultaneously with the tidal flow; whereas in the Mutla there is tidal water alone,—and not only that which fills its own bed twice in every twenty-five hours, but also, the tidal water which passes through it, while flowing into, and ebbing from the great reservoir channels of the Biddiadhurree and the Attara Banka, as well as to, and from, their branches, and the other Sunderbund Creeks. These are the distinctions in the conditions of the Hooghly, and the Mutla, to which, in the Author's opinion, are due the differences in their state as navigable channels. The result appears to him conclusive as to the value of tidal water alone, as compared with fresh water and tidal scour combined. By tidal scour alone, there is a deep and unchanging channel, free from bars and shifting sands. By the combined action of fresh water and tidal scour, there are shoals, shifting sands, variable channels, and a gradual, and it may even be said, a rapid shoaling of the lower channels of the estuary. The Author brings his views on these points prominently before the Institution, because he is aware, that during the discussion of the subject in the locality, one member of the Hooghly Committee, Mr. Piddington, a gentleman of well-known ability, entertained a contrary impression, attaching the greatest importance to the fresh water, as an agent of improvement, and looking to the increase of its quantity, as the chief and effectual means of remedying the present defective state of the Hooghly. Owing to differences of opinion, Mr. Piddington reported separately from his colleagues, and in concluding his Report says:—"I am earnestly desirous of drawing the special attention of Government (without, as I hope, overstepping my functions as a Member of the Committee) to, *First*, my remarks above (p. xvi. to xix.) on the deficiency in the nautical education of the junior members of the Pilot Service: *Secondly*, to the importance of obtaining for as long a period in the year as possible, a good supply from the purer waters of the Ganges to the feeders of the turbid Hooghly, to aid the downward sweep of the tides; and, *Thirdly*, to the advantages in point of celerity and safety, which might arise to the navigation of the river throughout, from any well-contrived and economical plan for stirring the mud and sands at the more difficult crossing places. With these efforts on our part, which I respectfully submit are naturally, and some of them indeed urgently, called for—and homely and self evident as a few simple efforts for the amelioration of the channels may appear, they are in truth scientific means of the first order, as seconding and carrying out the evident processes of nature: with these endeavours, then, intelligently directed and perseveringly carried on, I trust that, under Providence, it may yet be a far distant time ere our noble river will become more dangerous, or less navigable, for vessels of great burden, whether under sail or with steam, than it has been during any part of the present century."[1] Some of the witnesses appeared to participate in these opinions, and particularly Major Lang, the then Superintendent of the Nuddea rivers, that officer in his evidence having said:—"It is during the freshes, when the supply of water by the Nuddea rivers is very abundant, and when these rivers are well opened throughout, that the waterway of the Hooghly is made, and year after year preserved." The Author believes the views of Major Lang to be erroneous. It is not only the detritus brought into the Hooghly, by the fresh water from the Nuddea rivers, and that brought down by the Damoodah and the Roopnarain, that is prejudicial; but the action of the fresh water itself, which, when running in conjunction with, or in opposition to, the tidal streams, leads to the shifting of the sands, and the variation of the channels. A strong illustration of the correctness of this position is afforded, in the effects of the tides, and the upland waters, upon the sand-banks and channels, of the James and Mar Reach, which have already been detailed in a preceding part of this Paper.[2]

With reference to the suggestions put forward by Mr. Piddington, the Author will not say, that remedial measures could not be adopted; but he believes, that their effect would be small, and their expense very great. Moreover, he considers, that the effect of the proposed system of increasing the amount of fresh water, and of dredging, or raking over the shoals, would only increase the amount of deposit, and occasion the sands in the upper channel to shift, to a greater extent than at present. He, however, believes that an improvement might be effected, in the upper portion of the river, by turning the waters of the Damoodah from their present channel into that of the Roopnarain, which could easily be done, by making a cut of 4 miles in length, from near Bagnan, in a direction a little to the west of south. In view of the leading features of the James and Mary Shoal, the Author has arrived at the conclusion, that it owes its origin to the conflicting and varying influences of the freshes and tides, and particularly to the action of the Damoodah River. It has already been stated, that previously to the year 1762, that river joined the Hooghly above Calcutta. Had any records been in existence, it would have been interesting to have compared the past and the present state of the James and Mary Reach. There is, however, in Calcutta a well-authenticated tradition, that the James and Mary Shoal was formed in consequence of the change in the outlet of the Damoodah, and the Author has no doubt but that such was the case, for it appears evident, that if it were not for the discharge of the Damoodah, the set of the flood and ebb tide in the James and Mary Reach would, at all seasons, be along the western shore, and that a deep and permanent channel, on that side of the river, would be the necessary result. In considering the proposed change, a doubt may be felt, as to the effect of the increased volume of water discharged by the Roopnarain upon the Hooghly Sand, and the channels on each side of it. The Author therefore hopes that such members of the profession as have specially studied these subjects, will favour the Institution with their views on that point; his personal opinion being, that while the diversion of the Damoodah would effect a great improvement, in the removal of the James and Mary Shoal, it would not occasion any detrimental effect to the river below, and that the result would be, that the flood and ebb tide from the Roopnarain would then have a straight course, and that the Mukreeputty lumps being swept away by the ebb from the Hooghly, a fair way would be opened, into the then permanent western channel.

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[1] *Vide* "Reports, with Proceedings and Appendix, of the Committee appointed by Government to Inquire into the State of the River Hooghly." Calcutta, 1854.

[2] *Vide ante*, p. 10 *et seq.*

In the lower part of the river, the Author regards engineering works, as hopeless. The first effort of the river Engineer is to confine the flood and ebb tide to the same channel. How far works with that object could be executed, and how far, if executed, they would be effective, in an estuary from 7 miles, to 17 miles in width, and at what cost, it is impossible to say; but it may be confidently affirmed, that the risk of failure would be great, the expenditure of money large, and that the only certain result would be a considerable increase in the, already heavy, port-charges of the Hooghly.

In conclusion, respecting the presumed rivalry between the old port of Calcutta, and the new one of the Mutla, the Author cannot do better, than quote from the Report which he made in 1857, to the Directors of the Calcutta and South Eastern Railway Company, in which he said:—"It is feared by many, and perhaps with some show of truth, that the transference of a large portion of the trade of Calcutta to the Mutla would seriously depreciate the value of private property in Calcutta. But even if this were so, it could only arise from the country at large being greatly benefited by the creation of a new and admirable port. If it were not a public benefit, the trade would not be attracted there. If it be a public benefit, then private interests must not stand in the way. But, after all, is it so certain that Calcutta would be ruined by opening out the Mutla? For my own part I do not think it would be so. The trade of India is striding onward—it has done so under all its antiquated conditions. New facilities are at length being afforded to it. The railway system has been introduced, and so far as it has gone, has more than realized the most sanguine expectations of its promoters. It is only in its infancy. Within a few years, the vast system of the East Indian Railway, and probably the Eastern of Bengal Railway, extending upwards to the north-eastern districts of Bengal, will pour in an enormously increasing stream of traffic to Calcutta; and I doubt not that, ere many years are over, this trade will have obtained a development that will amply reward the proprietors of the new system of communication, afford an abundant business for both ports, and confer an incalculable benefit upon this magnificent country."[1]

The Paper is illustrated by a series of diagrams, from which Plate 1 has been compiled.

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[1] *Vide* "Report on the Calcutta and South Eastern Railway, from Calcutta to the River Mutla and the extension eastwards to Dacca and the Burmese provinces." By James A. Longridge. Page 20.

Mr. J. A. LONGRIDGE, in answer to questions, explained, that in making his estimate of the relative cost of the carriage of merchandise, by water and by rail, he had added for interest, an amount which was considered to be correct by the native dealers. The quantity of mud, estimated by Major Rennel to be brought down by the Ganges, was computed from the amount of deposit precipitated in a glass; whereas in the experiments made by Mr. Piddington, the mud was dried to the consistency of a sunburnt brick. Mr. Longridge believed, that the statement which had been made by Capt. Sherwill, as to the amount of mud deposited by the waters of the Ganges, was based upon observations.

Colonel SALE,—through the Secretary,—stated, that, owing to the increased trade of Calcutta, and the insufficient accommodation for shipping in the River Hooghly, but chiefly in consequence of the increased danger and difficulty in the navigation of that river, an inquiry had been instituted, as to whether any of the sea channels of the Sunderbunds could be rendered available for the purposes of the trade. The Mutla had been found to answer the requirements, as it possessed a safe and convenient navigation, with a tract of land suitable for warehouses and offices on its banks, within a moderate distance of Calcutta. The chief objection to the new settlement had hitherto been the unhealthiness of the site; but its salubrity would improve year by year, as embankments were being made to keep out high tides, the land was being drained, roads formed, and tanks, or reservoirs excavated, to hold and ensure, a good supply of pure fresh water. There were numerous applicants for the land, which was sold in allotments on building leases, and, by the construction of the Calcutta and South Eastern Railway, there was every prospect of the new port becoming a useful and necessary adjunct to Calcutta.

Mr. A. HENDERSON could not admit that the advantages of the Mutla, in a nautical point of view, were so great as had been stated in the Paper. During the S. W. monsoon its entrance was 30 miles to leeward of the entrance of the Hooghly. This circumstance alone would add greatly to the risks incurred by all vessels entering the Mutla; and to sailing vessels leaving that river during the S. W. monsoon, the foul wind would occasion a delay, quite equal to that which would be caused by the shoals in the upper part of the Hooghly. In reference to the case of the steamer 'Bentinck,' which had been mentioned in the Paper, it must be noticed, that prior to 1829, when steam-tugs were introduced on the Hooghly, no vessel of her size (2,000 tons) was allowed to load above Diamond Harbour. It, however, might be affirmed, that as the use of steam increased, the difficulties of entering either river would be overcome. The facilities for entering both rivers would then be equal.

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In their present state, the establishment of a new port, at the head of the Mutla, would be of great service to the metropolitan port of Calcutta. When Great Britain was looking to India as the future cotton field of Europe, and when endeavours were being made to open that country to commercial enterprise, the importance of a well-organised system of transit co-operation, by railways, by water, and by ferry-bridges, could hardly be over-estimated. As fifty millions sterling had been expended in trunk railways and canals, it would be necessary to improve and utilise to the utmost the river navigations, to act as feeders to those main lines, and to provide an additional number of river steamers. Since any alteration in the channels of the rivers, and especially of the great Delta, would be costly, and the result very uncertain, he contended, that it would be preferable to construct vessels, of suitable size and form, for the navigation of shallow and tortuous rivers, and, that economy of transit, in such cases, was mainly dependent on the suitability and efficiency of the engines and boilers, and of the steering and towing apparatus.

Mr. John Murray said, the question of the relative value of tidal and fresh water scour, was one of much importance in a professional point of view, but he could not agree with the theory put forward by the Author. On the contrary, he considered, that wherever land water was allowed to pass through a tidal channel, its action must be beneficial. If 1,000 tons of tidal water passed into a channel and ran out again, a certain scour would be produced, but if 1,000 tons of fresh water were added, then 2,000 tons would be running out in the same time, and a four-fold scour would be the result. He therefore thought, that some other cause, than the absence of fresh water must exist, which occasioned the greater and more uniform depth of the channel of the Mutla, as compared with that of the Hooghly. If the soundings on a contoured chart of the upper part of the Bay of Bengal were examined, it would be found, that there was a deep-water channel in the centre of the gulf, some portions of which had not been sounded at 300 fathoms.[1] This deep-water channel passed much closer to the entrance of the Mutla, than to that of the Hooghly, and in consequence, the tidal wave entered the former estuary under more favourable conditions, than it entered the latter. At the full and change of the moon it became high water at the River Naafe, on the coast of Chittagong, at 10 o'clock, and the tidal wave, crossing the upper part of the bay, produced high water at the nearest mouths of the Sunderbund creeks at about the same hour. The momentum of the wave, augmented during part of the year by the force of the south-west monsoon, struck the bottom in 100 fathoms; and as the soundings, opposite the mouth of the Sunderbund creeks, decreased suddenly to 5 fathoms, in a distance of only 5 miles, a steep gradient in the foreshore, of 1 in 50, was produced. The abruptness of this rise arrested the tidal wave, until it attained sufficient head to reassume its progressive motion. It then rushed forward with great impetuosity into the Mutla and the adjacent creeks; but the entrance to the Mutla being nearest to the deep-water of the Bay of Bengal, and hence its channel being in immediate connection with the course of the flood tide, there was always a free current into it, and sufficient depth of water to form a navigable channel for vessels of the largest class. The River Hooghly, on the contrary, being the most westerly of the sea entrances of the Delta, received the tidal wave at a later period, and the flood tide, having to traverse the shoals at its mouth, did not reach Diamond Harbour until 12 o'clock, being about two hours after it had reached the head of the Mutla, which was nearly in the same latitude. The most violent winds in the Bay of Bengal were from the south-west, and when accompanied by a spring tide, the littoral of Hindostan was swept from its southern extremity to the mouth of the Hooghly. Under these circumstances, the force of the flood tide was checked by the sandbanks at the entrance of that river, and the tidal wave breaking, formed a dangerous bore. With north-east winds, the deep water of the centre of the bay, and along the whole length of the gulf, was forced seawards, and was the cause of littoral counter currents running northwards, carrying with them the detritus to the head of the bay on both sides. Hence, the preponderating power, both of the tidal and river currents, was such as to cause the deposit to take place on the part of the bay in which the entrance to the Hooghly was situated, and thus to occasion its channel to be shoaler than that of the Mutla.

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[1] *Vide* Plate 1, Sketch Map of the Delta of the Ganges and of the Bay of Bengal.

In regard to the amount of solid matter contained in the waters of the Hooghly, although Major Rennell had, in his "Memoir of Hindostan," estimated the water of the Ganges to consist of one-fourth part mud, yet, in other writings, he had given it as only the $\frac{1}{200}$th part. The latter estimate agreed better with Mr. Piddington's experiments, which showed the quantity to be the $\frac{1}{613}$th part, and with the Rev. Mr. Everest's, who made it the $\frac{1}{856}$th part, both during the rainy season. The Nile contained $\frac{1}{120}$th part of its bulk in mud, and the Humber $\frac{1}{180}$th part, of which latter, sand formed about 75 per cent. But even allowing that 78,000,000 cubic yards of solid earth were deposited yearly, in the Hooghly and its estuary, this would only give $1\frac{1}{2}$ inch in depth, over an area of 600 square miles, included within the 3-fathom contours; and if the area was extended to the 5-fathoms contour, and embraced also the inlet of the Hooghly, then the area would be 1,200 square miles, and the deposit would only amount to ¾ inch in depth per annum.

A belief existed, that much had been done by the former Government of India, to facilitate a boat passage from Calcutta, through the Sunderbunds. But by a return to Parliament the amount expended with that object appeared not to exceed £37,000; and the chief outlay upon the canals, in the immediate vicinity of Calcutta, had been incurred in throwing bridges across the streams, and in making roads on the banks, and scarcely any, in straightening the water courses, or in deepening them, either by manual labour, or by dredging. One of the three Nuddea rivers, now only navigable during the months of July, August, and September, might have been rendered fit for navigation, throughout the year, not only for the native boats, but also for the light-draught steamers trading on the Ganges. According to a parliamentary return, the average cost per annum, extending over ten years, of maintaining these rivers, including salaries and the whole establishment, was £3,284; whilst the average tolls, after deducting the expense of collection, amounted to £14,486 per annum. There was, therefore, a considerable balance in hand, which might be laid out in straightening the best of these channels, deepening its bed and raising its banks, and in executing other engineering works, calculated to maintain a sufficient depth of water in it for the purposes of navigation.

Turning now to the Sunderbund district, it would be found, that it comprised an area of 4,500 square miles of low lands, inundated during the rainy season, by the overflowing of the numerous rivers and water courses, producing a rank vegetation, and overspread, in most parts, by a dense jungle, the hotbed of fever, fatal to human life. The miasma from this jungle must, with certain winds, be carried to the cultivated districts, and even to Calcutta itself. If a proper system were adopted, of dividing this extensive and at present useless territory into districts, by a series of cuts, surrounding them by embankments, and allowing the water when charged with sediment to remain for a time within them, and run off at low tide, the land would rapidly be warped up, probably at the rate of 2 feet, or 3 feet in a season, and thus might be made to contribute an ample return of valuable produce, by a similar process to that, which for many years past, had been so successfully adopted on the borders of the Trent, the Ouse, and other rivers in connection with the Humber.

Mr. J. R. M'Clean, V.P., observed, that the Barrow Estuary, or Strait between Walney Island and the coast of Lancashire, on the north side of Morecambe Bay, afforded another illustration of a channel kept open by tidal scour alone. The flood tide arrived in the Duddon Estuary, at the north end of Walney Island ten minutes earlier than at Piel, at its southern extremity; and the difference of surface level thus produced occasioned the tide to ebb, for nearly 5 hours, in the same direction. This almost uniform scour in one direction was no doubt the reason, that the channel of Barrow Estuary maintained its depth. There was no accretion on the margin of the estuary, but the strength of the tide, along the shore, was so great as occasionally to denude the coast.

Mr. A. GILES, did not concur in the theory which had been put forward, that a tidal channel could be maintained in a better state if no fresh water were allowed to run through it. In the case of the Barrow Estuary it was obvious, that if a dam were placed across the channel to the north of the town of Barrow, the estuary would silt up. The harbour at Portsmouth, and, in a less degree, that at Ramsgate, were also instances of harbours silting up for want of fresh-water scour, which he contended should always be sought for as a useful auxiliary towards keeping a channel free from deposit. As regarded the Hooghly, it was obvious that the quantity of fresh water which came down the channel at Garden Reach, when augmented by the waters of the Roopnarain and the Damoodah, could not easily be confined in the wide portion of the river below Culpee. There the tides and fresh water alternately struggled for the mastery, and sandbanks were deposited owing to the streams neutralising each other. The monsoons also were partly the cause of the changing character of the sandbanks, so that the Hooghly might be considered an exceptional case, but in the absence of data, by which to determine the relative velocities of the streams in the two estuaries, it would be impossible to arrive at any conclusion, as to the causes which had contributed to the relative superiority of the Mutla.

Although it might be possible, to bring traffic to the New Port at the Mutla, by means of the Calcutta and South-Eastern Railway, yet the enterprise would have great difficulties to contend with, from the interests connected with the existing navigation by the Hooghly. When Southampton was united to London by a railway, it was thought that vessels would avail themselves of that port, to avoid the dangerous navigation of the English Channel, and that, in consequence, it would become the port of London: twenty years' experience had however proved, that although Southampton had acquired a considerable traffic, it had not succeeded in diverting trade from London. He considered the question of the probable diversion of the traffic of Calcutta, from the Hooghly, to the Mutla, a parallel case.

Mr. HAWKSHAW, V.P., considered, that it was quite as erroneous to lay down as a rule, on the one hand, that fresh water was of no use, as, on the other, that a channel could not be kept open without fresh water. In nature, every possible condition was to be found; in some cases the fresh water, and in others the tidal water, greatly preponderating, and their relative quantities ever varying. A channel would always be maintained, if the water flowed through it with sufficient force to prevent deposit, whether the stream was continuously in one direction, or whether it oscillated backwards and forwards.

Mr. W. A. Brooks believed, that the real cause of the difference in the capacity of the navigable channels of the Hooghly and the Mutla, arose from the fact that the flood and ebb tides both took the same course in the Mutla, whereas they entered and left by different channels in the Hooghly. If the chart of the Hooghly was examined, it would be seen that below Culpee Roads there was an expanse of sandbanks and shoals, which occupied nearly three-fourths of the high-water channel opposite to Saugor Island. These were evidently caused by the deflection, to the south-west, of the ebbing current from the Culpee Reach, the sand being deposited in the eddy which it created. A similar deposit, from like causes, was also formed to the south-westward of Saugor Island, and also in other localities in the upper part of the river. He believed, that the average depth of the Hooghly was greater than that of the Mutla, and that the difficulty of navigating the former river, was solely owing to the necessity which existed, for crossing over the bars, which separated the flood from the ebb channels. As to the utility of fresh water as a scouring power, he contended, that the depth in the channel of the Mutla had been originally created, not by tidal scour alone, but by the land waters of the Ganges, which had in former times opened out the course now taken by the tide; and that so long as there was an absence of any great quantity of mud in the channels, it must remain open. There were several other examples in India of channels which were in a very good condition, where there was little, or no fresh water, though they had been originally made by the water from the land. The easterly and westerly branches of the Indus, were at the present moment both tidal estuaries, and other estuaries of similar origin might be named.

Lieutenant C. V. Ward, I.N., confirmed the statements contained in the extracts from his Report which had been quoted in the Paper,[1] and added, that the survey he had made for the Indian Government was not of an engineering character, but had been limited to the nautical purposes in view. In his opinion no practical difficulty would arise during the S.W. monsoon from the entrance to the Mutla being 30 miles to leeward of the entrance to the Hooghly. During the same monsoon vessels left the port of Ackyab on the coast of Aracan, although that port was on a lee shore, hence, there could be no danger in the case of a vessel leaving, or entering, the entrance of the Mutla, which was so much more favourably situated.

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[1] *Vide ante*, p. 18.

Mr. AYRTON, M.P., observed, that no great faith could be placed in any scheme for the improvement of Indian rivers, inasmuch as for eight, or nine months in the year the weather was perfectly dry, and for four months in the year, the rainfall produced a flow of water unprecedented in this country. About the year 1831, the Government caused a survey to be made in reference to the construction of a canal from Calcutta to the head of the Mutla, but the execution of the canal was postponed from year to year, until at last it was decided, that a railway should be substituted for the canal. He regretted that decision, as he believed, that the formation of a canal was the only effectual mode of dealing with the question of the navigation to Calcutta. With respect to the change of the seat of trade, from Calcutta to the Mutla, there were as many difficulties in the way, as if the attempt were made to transfer the trade of the Thames at London, to the Medway. If millions of money had been sunk in the erection of warehouses and buildings, for the purposes of trade, that was an element quite as important as the question of the navigation of the river itself. Looking to these facts, and to the delays and cost of unloading a cargo, 20 miles, or 30 miles, from the place to which it was consigned, and of conveying it that distance by railway, he thought, that for all commercial purposes the trade would be continued to be carried on at Calcutta. There was a practical difficulty in carrying on trade in vessels of the large dimensions which had been mentioned; but should they be used, they would no doubt go up the Mutla in preference to the Hooghly.

Mr. J. HORATIO LLOYD observed, that as Calcutta would be connected with the Mutla by railway, its commercial position would remain unaltered by the adoption of the navigation of that river. The object proposed to be attained was not that of superseding Calcutta as a commercial port, but that of enabling the traffic to reach it in the easiest manner.

Mr. JOHN BORRADAILE remarked, that the difference of expense to the merchant, in using the port of the Mutla, or that of Calcutta would be considerably in favour of the former port. He thought that preference should be given to a river where there was always 24 feet of water, to one which was beset with shoals; and to a river, the mouth of which was only 50 miles from the head of the navigation, available in one day's steam, to one which required three days' steam, in a country where steam-power was costly. It was not a question of superseding Calcutta as a port of commerce, but the Port of Mutla would form a valuble auxiliary—like Birkenhead to Liverpool. By the route advocated, the physical difficulties of the approach would be lessened, and the same point arrived at, with diminished risk and greater economy.

Mr. Bidder,—President,—in closing the discussion, said, that there was always great difficulty in changing the locality of an important commercial business. No doubt there were large establishments at Calcutta, with all the accessories for the trans-shipment of goods. Granting that the Mutla had all the advantages ascribed to it, a long and severe struggle would be made on behalf of existing interests. But so far as the Mutla was concerned, it should not be considered as hopeless, especially as it had been stated, and not denied, that it possessed an unchanging channel, accessible at all times. As Southampton had been cited, it might be said, that although the heavy merchandise trade had not been drawn there, yet that port was resorted to by the trade requiring quick transit—mails and passengers. In like manner, probably, the first vessels to frequent the Mutla would be the steamers carrying the mails, for which speed was the main object, and in the course of time it might receive a share of the heavier trade. As regarded the comparative value of tidal and of fresh-water scour, he feared, that there was not sufficient information relative to the physical features and the conformation of the rivers described in the Paper, to enable any well-defined conclusion to be drawn from them. Great credit was, however, due to the Author for the care with which he had grouped and analysed the facts at his command. He hoped, that at some future period the question would be brought before the Institution, in some case where sufficient data existed for an extended and useful discussion, on that important branch of hydraulic science.

Long Tube Barometer.

After the meeting, Mr. R. Howson exhibited in the Library a barometer, consisting of a long tube, freely suspended with the open end downwards, a cistern which was of a tubular shape, and a 'stalk.' The stalk was a glass tube, sealed at both ends, attached firmly at its lower end to the bottom of the cistern, and rising axially up the tube, until it nearly reached the surface of the mercurial column. The consequence of this arrangement was, that the top of the stalk came into a region of very low pressure, and there was an excess of pressure tending to force the cistern upwards. This excess was represented by the weight of the cistern (and the stalk), and the contained mercury, so that under a given atmospheric pressure, the cistern would always hang suspended at a given level. When the pressure of the atmosphere rose, a portion of mercury left the cistern and passed into the tube, and the cistern also rose, until the level was replaced by the immersion of the glass which formed the tube. When the pressure fell, the converse took place. An elongated scale was thus produced, the extent of range being dependent upon the relative areas of the tube, and of the glass which composed it. The action might also be simply viewed as that of a long piston, or plunger, with a liquid packing, having a vacuum on its upper side, and a self-graduating weight attached to its lower side.

November 26, 1861.

J. R. M'CLEAN, Vice-President,
in the Chair.

No. 1,045.—"On Measuring Distances by the Telescope."

By WILLIAM BAYLEY BRAY, M. Inst. C.E.

THE Author's attention was attracted to this subject by a Paper by Mr. Bowman, which was read before the British Association in 1841.[1] In the method of measuring distances put forward by that gentleman, the number of divisions of a staff, which were subtended by the diaphragm, or field of view of a telescope were observed, and from that measurement, the distance of the staff from the centre of the telescope was ascertained by calculation, or by the use of auxiliary tables. One objection to the practical application of the method, as then put forward, arose from the diaphragm, or field of view of a telescope, not being sufficiently defined, for the purpose of measuring the divisions on the staff. To obtain accurate readings, it would be essential that they should be observed by means of hairs as fine as those which are ordinarily used in taking levels. The subsequent calculation, or tabular inspection, might also be dispensed with, if the distance hairs were so placed on the diaphragm as to subtend 1 foot on a staff, at a distance of 1 chain, and 10 feet on a staff, at a distance of 10 chains. In practice, the Author found that it was more convenient to have two distance hairs on the diaphragm of a levelling instrument, one about $\frac{3}{20}$ of an inch above the level hair, and the other as much below, so that either of the distance hairs could be used as a fellow to the level hair, for the purpose of measuring the distance. He also found, that under certain circumstances, these distance hairs were of great use in levelling. It frequently occurs, that the level of some point is required which is so low, that although the levelling staff is visible in the field of view, yet it cannot be intersected by the central horizontal, or level hair of the instrument. In such cases it is customary for the staff-holder to raise the bottom of the staff on to his chest, or shoulder, and the approximate height of the bottom of the staff, above the ground, is then added to its reading. This mode of overcoming the difficulty occasions loss of time, and is by no means trustworthy; but if the level is provided with distance hairs, there is a great probability that the staff will be intersected by the lower distance hair. If the division at which it intersects the staff is noted, and then by means of the level screws the telescope is depressed, until the level hair intersects the staff, it will only be necessary to add the measurement, subtended between the level hair and the lower distance hair, to the original reading of the lower distance hair, and the sum will be the correct height of the level of the instrument above the bottom of the staff. In like manner, in case of need, the height of a bank, or any other point a few feet above the level of the instrument, can be taken by means of the upper distance hair.

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[1] *Vide* "Report of the British Association for the Advancement of Science, 1841—Transactions of Sections," p. 42. Also "The Civil Engineer and Architect's Journal for 1841," p. 425, where the Paper is given *in extenso*.

The use of these distance hairs for eighteen years has proved their practical value. The widths of rivers and of deep ravines have been rapidly and easily taken by them, and distances of 20 chains have been read in favourable weather. If the compass is sufficiently delicate, any operation of contouring, or of running trial levels, can be performed by their aid with rapidity and exactness, and when they are accurately fixed on the diaphragm, they may be used even for fractions of a link, in taking widths incapable of direct measurement.

As regards the theoretical limit of the accuracy of the method now proposed by the Author, it is evident that if the distance hairs remained at an invariable distance from the object glass, the portions of the staff intercepted by them would be strictly proportional to the distance of the staff from the object glass. Since, however, in focussing the instrument to any object, it is necessary to bring the cross hairs into a new focus, which is proportionally further from the object glass as the object is nearer, the angle which the hairs subtend from the centre of the object glass must be variable, diminishing as the distance diminishes, and in consequence the portion of the staff intersected at short distances is too little. If the distance hairs subtend 10 feet at a distance of 10 chains, it will be found that they subtend 0·985 feet at a distance of 1 chain, instead of subtending 1 foot, which they would do by inverse proportion. Hence a correction is necessary, and this the theory of refraction by lenses furnishes. It shows that the error is constant at all distances, amounting, in every case, to the focal length of the object glass for parallel rays. In fact, the portions of the staff, intercepted by the distance hairs, are strictly proportional to the distance from the anterior focus of the object glass.

If, therefore, the hairs be so placed on the diaphragm, that at the distance of 10 chains from the anterior focus, they subtend 10 feet, at the distance of 1 chain from the anterior focus, they will subtend 1 foot, and at a distance of 20 links from the anterior focus they will subtend 0·20 feet. As these distances are all measured from the anterior focus, the constant focal distance for parallel rays of the instrument, must in each case be added to the distance observed by means of the staff, as well as the distance from the object glass to the centre of the instrument, which is also a constant quantity. In the instances of a five-inch theodolite, and of a ten-inch level, the sum of these two constants is about 16 inches, or 2 links. This amount should be added to the distance, when reading the number of divisions subtended on the staff. The easiest mode of doing this, is by bringing the lower cross hair near any even division of feet, but exactly 0·02 feet above it, and then reading the intersection of the upper distance hair as shown on the staff. The difference between the even division at the lower hair, and the upper reading, will then be the number of divisions which represent the distance.

When distance hairs are applied to a theodolite, they can be used for measuring distances on sloping ground. But in that case, since the line of sight is no longer perpendicular to the staff, a larger portion of the staff is subtended by the hairs, than is due to the correct distance. If the correction for sloping ground, graduated at the back of the vertical arc of the theodolite, is deducted from the quantity subtended by the distance hairs, the remainder will be the sloping distance, and if twice that correction is deducted from the quantity subtended, the remainder will then be the horizontal distance. An additional power is obtained both in the theodolite, and in the level, by having a second pair of distance hairs so placed on the diaphragm as to read the distances in feet, instead of in chains, and so that either of these feet distance hairs may be used, in combination with the centre level hair of the instrument. In the theodolite they are of great use in taking cross sections of sidelong ground, or determining by one observation of the staff any rise or fall even of 100 feet, or more. But for these purposes an auxiliary table is requisite, similar to the one on the next page.

In measuring the height or depth by the aid of these Tables: when the horizontal distance to the staff has been ascertained, the telescope of the theodolite is to be elevated to the tabular angle, corresponding to the fractional rise, nearest to the slope of the ground; then that fraction of the horizontal distance, less the reading on the staff, will be the correct rise. Thus, if the horizontal distance is found to be 380 feet, and the fractional rise is 1 in 5, the telescope of the theodolite must be set at an elevation of 11° 18½′; and supposing the centre horizontal hair cuts the staff at 3·00 feet, the rise will be $\frac{380}{5}$ feet $-$ 3 feet $=$ 73 feet. A sufficient number of distances and heights to form a cross section, may thus be rapidly taken with sufficient accuracy for ordinary purposes.

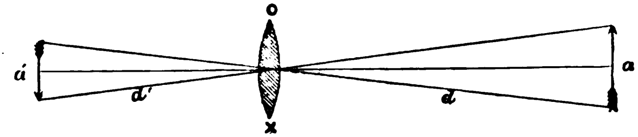
TABLE of SLOPES and of their CORRESPONDING ANGLES, together with the amount per cent. to be deducted from the sloping distance, to find the horizontal distance.

Slope.	Corresponding Angle.			Amount to be deducted.	Slope.	Corresponding Angle.			Amount to be deducted.
1 in	°	′	″	Per Cent.	1 in	°	′	″	Per Cent.
1	45	0	0	29·37	16	3	34	35	0·19
2	26	33	50	10·55	17	3	21	59	0·17
3	18	26	5	5·12	18	3	10	47	0·15
4	14	2	10	3·00	19	3	0	46	0·13
5	11	18	35	1·97	20	2	51	45	0·12
6	9	27	44	1·38	21	2	43	35	0·11
7	8	7	49	1·01	22	2	36	9	0·10
8	7	7	30	0·78	23	2	29	22	0·09
9	6	20	25	0·62	24	2	23	9	
10	5	42	38	0·50	25	2	17	26	0·08
11	5	11	40	0·41	26	2	12	9	
12	4	45	49	0·35	27	2	7	16	0·07
13	4	23	55	0·30	28	2	2	43	
14	4	5	8	0·25	29	1	58	30	0·06
15	3	48	51	0·22	30	1	54	32	

By fitting the telescope of a level, or a theodolite, with a second pair of distance hairs to measure the distances in feet, a further advantage is incidentally obtained. It sometimes happens, that the greater part of a staff is hid from view by hedges, or other obstructions; as, for instance, a case may occur when at 10 chains' distance only 3 feet, or 4 feet, of the upper part of the staff are visible. Now at a distance of 10 chains the portion of the staff which would be subtended between the upper foot distance hair, and the upper link distance hair, would be 3·40 feet. Assuming this quantity, or any other, to be observed, the approximate distance can be obtained, by multiplying the observed interval by three, thus: 3·40 feet × 3 = 10·20, and the correct distance can subsequently be obtained by deducting two links from each chain, thus: 10·20 − 0·20 = 10 chains. In clear weather, with a distinct reading staff, a distance of 40 chains has thus been determined, by the interval of the staff which was read between the foot and link hairs.

Mr. **Gravatt** said, that as long ago as the year 1828, he had used the dumpy level for measuring distances, and by doing so, had been able on many occasions to dispense with chainmen. He was aware that several other Engineers had also adopted the same system, but possibly its application might hitherto have been limited, from the want of a correction for the errors introduced in focussing the instrument. He thought that point had been rightly treated in the Paper, but it would be well that the theory of the matter should also be correctly understood.

Fig. 1.

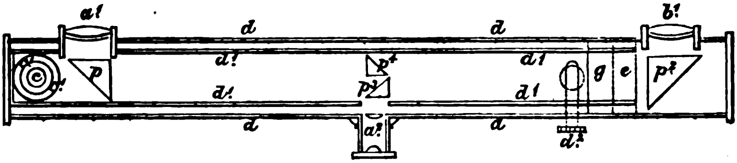


In Fig. 1, if O X represented the object glass, a the direct image, and a' the inverted image formed within the telescope, then $\frac{d}{d'} = \frac{a}{a'}$, and by the common focal theorem, when f represented the principal focal length of the telescope, $\frac{1}{d'} + \frac{1}{d} = \frac{1}{f}$, by means of which two equations, and eliminating d', the equation $d = \frac{f}{a'} a + f$ was obtained, as given in most of the books which treated of optics. It was therefore evident, that if a cross hair was fixed on the diaphragm of a telescope, at a distance from the centre level hair of $\frac{1}{66}$ of the principal focal length of the telescope, then at a distance of one chain, plus the principal focal length, a space of one foot would be subtended on the level staff, and in a similar manner at a distance of n chains, plus the principal focal length, a space n feet would be subtended on the staff. The preceding distances being from the object glass, it was necessary to add the distance from the object glass to the centre, or vertical axis of the instrument, before the distance to the centre of the instrument could be obtained. In the dumpy level, the distance from the anterior focus, added to the distance from the object glass to the centre of the instrument, amounted to about 2 links. So that assuming a space of 3·45 feet was subtended on the staff between the cross hairs, the true distance from the staff, to the centre of the instrument, would be 3·47 chains; or, if 5·67 feet on the staff, were subtended between the cross hairs, the true distance would be 5·69 chains; or, generally, if n feet were subtended on the staff, the distance from the staff to the centre of the instrument would be *n* chains plus 2 links. He believed, that the instrument makers generally ascertained the distance apart, at which the cross hairs should be placed, by means of Troughton's micrometer, and then, with great care cut lines on the diaphragm to indicate the correct position at which the ends of the hairs were to be fixed. In his original level, he made both the upper and the lower cross hairs adjustable, with regard to the centre hair, and used, in addition, a Cavalho's mother-of-pearl micrometer. With an instrument of that construction he had frequently measured a distance of 17 chains. With a longer staff than was ordinarily used, no doubt a greater distance could be measured, but to measure distances accurately by this method, practice in reading the staff at known distances was essential.

Captain W. S. Moorsom, said, that the Paper, and the illustrations given by Mr. Gravatt, had considerably modified his opinion as regarded the utility of the micrometer. He had previously considered the micrometer to be an instrument more adapted for the general purposes of military reconnaissance, than for ascertaining the minute details which were required in engineering surveying. From what had transpired, there could however be no doubt but that it might, with great advantage, be more generally applied to many of the practical operations connected with levelling. His previous experience had satisfied him, that a quick and accurate observer could rapidly ascertain, with sufficient correctness for military purposes, the movement of a column of troops, the situation of forts, or of batteries of position, or the speed and course of vessels at sea. One telescope which he had used, was made by Mr. West, of Charing Cross. It had six cobweb wires across the diaphragm, and was fitted with a bronzed prismatic compass in the cover of the field-glass. With similar additions any ordinary telescope might be converted into a portable surveying instrument. He must however incidentally notice, that no bright brass fittings should be used in instruments intended for military purposes, on account of their affording an immediate mark for the enemy's sharpshooters. Happening to be on a part of the coast of Dorsetshire when the 'Great Eastern' made her first voyage out of the Thames, he was enabled to ascertain her rate of progress by means of a watch with a second-hand, and the micrometer and compass which he had just described. He laid the telescope and compass on a stone seat, which was conveniently situated for the purpose, and when the extent of the vessel, from stem to stern, covered a certain number of wires, he noted the time and the bearing. After an interval had elapsed, he found that the extent of the vessel from stem to stern covered a greater number of the wires, and he again noted the time and the bearing. Having ascertained the proportional angle subtended by the micrometer wires, he was enabled, by taking the length of the 'Great Eastern' as a base, to compute the distance at each observation. For although her course was not directly at right angles to the line of sight, the amount of obliquity was so small as not to vitiate the results. By plotting her position at each time of observation from the bearing and distances thus obtained, he was enabled to ascertain that her speed was from 13 miles per hour, to 14 miles per hour, and that she was steering in a direct line for Portland Breakwater.

Mr. P. ADIE remarked, that the arrangement described by the Author was of a much earlier date than had been mentioned in the Paper. He had been acquainted with the system for the last twenty years. It had also been very generally employed in deer-stalking. In the telescopes used for that purpose, there were different spaces in the diaphragm which subtended the height of a deer at certain given distances. He however doubted that the system could be used with accuracy for military purposes, as owing to the varying stature of different individuals, the distance deduced from the height of a man would probably be subject to a variation of as much as 20 per cent. In measuring distances by the telescope, it was of the greatest importance to substitute, if it possibly could be done, a certain for an uncertain base. With this view he had designed a small instrument which he exhibited. It consisted of two telescopes, the tube of one, working inside of the tube of the other, the object glasses of the two telescopes being placed at right angles to their respective tubes, at a distance apart of 18 inches from centre to centre, the rays of light being reflected by means of prisms to an eye-glass in the middle of the instrument. The interior details would be best understood by reference to Fig. 2:—

Fig. 2.



In the above figure *d*, *d*, *d*, *d*, represented the outer tube, which as it bore a fixed divided segment at *e*, might be called the limb of the instrument. At one extremity of the outer tube there was an object glass b^1. A totally reflecting prism at p^2, received the rays formed by this object glass, and reflected them along the inner tube d^1, d^1, d^1, d^1 to a prism reflector at p^3, which again reflected them into the upper half of the eye-piece a^2. The inner tube or vernier arm d^1, d^1, d^1, d^1, carried its vernier at *g*, and had a female centre c^1, c^1, fixed to it at its other extremity; this worked upon a male centre at c, which was fixed to the limb, or outer tube. The object glass a^1, belonging to the inner tube was fixed to it on the same plane, and at a given distance from the object glass belonging to the outer tube b^1. There was also a totally reflecting prism fixed to the inner tube at p, which received the rays from the object glass a^1, and reflected them along the inner tube to a second reflecting prism p^4, also fixed to the inner tube, by which the rays were again reflected to the lower half of the eye-piece a^2. The object glass a^1, the prisms p^2 and p^4, and the vernier g, being all fixed to the inner tube moved along with it: the pointing of the two telescopes being adjusted to suit the distance by means of the tangent screw d^2. In using the instrument, the two images of the object were not allowed to overlap each other, but were made continuous. By this arrangement simultaneous observations were obtained by two powerful telescopes, and the distance between the object glasses a^1 and b^1 being known, the angle between their directions, or in other words, the angle formed by the inner and outer tube, was read on the limb at e, in parts of degrees, by means of the vernier, and by reference to a tabular scale exposed on the instrument, the distance might at once be determined. As the time occupied in observing and reading the angle, only amounted to a few seconds, as many observations could be made as might be required for the attainment of an accurate result. It was always best to direct the two telescopes to some well-defined line or mark in the object, the distance of which was to be determined. With an instrument like that exhibited, which had the two object-glasses eighteen inches apart, distances exceeding two miles could not be accurately measured, and a larger instrument would be required. As the distance increased, the accuracy of its measurement, by the instrument, decreased. At one mile, the greatest error would be about 20 feet, while at two miles, the greatest error would be about 40 feet. In distances of less than one mile, a greater degree of accuracy was of course attainable. The great advantage which this instrument possessed, over others used for measuring distances, arose from the fact, that the accuracy of the operation was in no way dependent upon the knowledge of the dimensions of the object from which the distance was measured. The instrument was the only one that he was acquainted with, by which an angle of two seconds could be ascertained, and in all the ordinary modes of measuring distances by the telescope, it was essential that angles should be determined to that degree of minuteness. It was true, that in engineering operations, distances were sometimes obtained by measuring bases of from 50 yards, to 100 yards long, and that in that case, the angles did not require to be so minutely read; but, on the other hand, it must be remembered that in such cases the base had each time to be accurately measured, an operation which could not be performed without a considerable loss of time, and that there were two angles to be observed, which if they were small, was a difficult task to execute with a pocket sextant, so that in most cases, the loss of time involved by adopting that method would render it practically unavailable when immediate results were required.

Mr. G. W. HEMANS remarked, that although the system of measuring distances by the telescope had undoubtedly been known for the last twenty years, or more, yet it was possible that its application might hitherto have been limited, from the want of a correction for the errors introduced in setting the instrument to the focus corresponding to the distance, which having now been supplied, the method would probably come into more general use.

Mr. METFORD stated, through the Secretary, that he had for many years been acquainted with the method of measuring distances by the telescope, which had been described in the Paper, and from the results of his personal experience could testify to its practical utility. The instrument which he used was a Gravatt's 10-inch dumpy level, in which the distance hairs were so placed on the diaphragm as to subtend half a foot on the staff for each chain of distance. By means of these distance hairs, he had been enabled to find out old hidden stumps, for the purposes of levelling over them, and when tested by accurate measurement, the total error per mile in the distance measured by the telescope, did not exceed four links. He was thus enabled, by the use of the staff and distance hairs, to dispense with the assistance of chainmen. When in levelling operations the distance was measured by the distance hairs, it was desirable, that the levelling instrument should have the power of measuring horizontal angles, as it frequently occurred that it was necessary to place it out of the line along which the distance was measured. He had also lately applied the system of dividing the field of view of the telescope, to certain purposes connected with rifle practice. After numerous experiments, he had succeeded in cutting several concentric circles and radial lines on glass, with a diamond fragment, so that they would be visible in the field of view of the telescope. When the glasses were placed in the field of view, the grooves, or lines appeared black, and it was found unnecessary further to blacken them. By the use of these grooved glasses, he had been enabled to do away with the necessity for a marker at the target, as he found that if a white spot to aim at was marked on an upright butt, an observer, by means of the concentric rings, and radial lines, could localize and read the exact position at which the shots struck. This method of noting and recording the shots, possessed decided advantages over the ordinary method of mark-ing a target in squares, and employing a marker at the target, and a recorder at a telescope stationed near the experimentalist. According to the system usually adopted in private shooting ranges, the marker was obliged to come out from his shelter and point out the place where the shot had struck the target, the recorder on his part identifying this position by means of the telescope, and noting it upon a paper previously prepared with squares similar to those shown upon the target. In the first instance, Mr. Metford divided the surface of the glass, which he introduced into the telescope, into squares, in accordance with the usual system of recording the shots; but upon trial he found that the system of concentric rings, and radial lines, enabled him at once to determine the value of the different shots in relation to the centre. In one telescope, with a magnifying power of fifteen, the spaces between the circles subtended four inches at one hundred yards. In another, of a magnifying power of twenty-three, the spaces between the circles subtended two inches at a distance of one hundred yards. There was, however, one advantage which the system of recording by squares possessed over that of recording by concentric rings and radial lines, namely, that the mean centre of the shooting could be more easily ascertained. It was also more difficult to cut the concentric and radial lines than the vertical and horizontal lines; but with either system, when the height or the length of the target was known, its distance could be easily ascertained.

Captain **Moorsom** considered, that for measuring distances, the pocket sextant was a preferable instrument to that which had been exhibited by Mr. Adie. In using that instrument the base would only be 18 inches, whereas with the pocket sextant, a line could be laid off at a right angle to the direction of the object, along which, a longer and more convenient base could be measured. The acute angle at the other end of the base being then ascertained, the distance of the object could at once be accurately determined.

Mr. J. **Scott Russell** observed, that there were many methods of measuring distances, which, although they appeared very rough, were yet extremely useful as approximations in trial surveys. Referring to the example which had been given of determining the speed of the 'Great Eastern,' he would notice another method by which her speed might have been determined, or that of any other vessel, when the length was known. If the exact time at which the stem of a vessel passed a given line was noted by a watch indicating seconds, and the exact time at which the stern passed the same line was also noted, the interval between the two observed times would give the time in which the vessel had passed over her own length, no matter in what direction she was going. To determine the speed was only then a matter of simple proportion. Taking the example of the 'Great Eastern,' if it was observed that she had passed through her own length in 35 seconds, then her speed would be 20 feet per second, or 13·64 miles per hour. It had been asserted that the actual speed attained by the 'Great Eastern' fell considerably short of that which had been originally expected by those who designed her, but that was a mistake. Those who were in a position to know what speed was expected from her, always estimated it about 14 knots per hour as the average, and almost 15 knots per hour as the maximum. It was true that a greater speed had been anticipated by those unacquainted with the matter. The only way he could account for the error was, that a famous builder of American sailing-ships, but not of steam-ships, and who was accustomed to guess the speed of vessels by their shape, without reference to their power, came over to this country, and when he saw the 'Great Eastern' he was so pleased with her lines, that he said, "I will undertake to say, from the shape of this vessel alone, she will go 20 knots an hour."

While upon the subject of approximations he would also notice another rough-and-ready mode of surveying, which as a young man, he had adopted with success. On one occasion he had to ascertain the area of a large lake. It so happened, that he had two instruments by which angles could be measured with great minuteness. A base line was carefully set out, and one of the instruments was set up at each of its extremities, in charge of an assistant. A man with a staff was then sent round the margin of the lake, with instructions to stop at a given number of stations and to hold the staff upright. The two assistants, at the two extremities of the base-line, took simultaneous angles to the staff each time it was held up, from which, the positions of the several stations were determined, and in this way, although the lake was a very large one, and would have taken a long while to survey by the ordinary methods, its contour was mapped in a few hours, and he was enabled at once to calculate, how much its contents would be augmented, or diminished by raising, or lowering the level of its surface.

Mr. ALEXANDER GORDON said, that about twenty-four years ago, he witnessed the manner in which Mr. Scott Russell measured the speed of a new steamer called the 'Fire King' on the Clyde. The apparatus used was made by Dent; it was not strictly a watch, although somewhat similar. The second hand of the apparatus was split, so that measurements could be taken in parts of seconds. A line was set out in a direction at right angles to the course, and the speed of the vessel was measured very accurately by using her length as a base, and by taking the interval of time which was occupied between the successive passages of the forepart of the ship, and of the after-part of the ship. Such a method of measuring the speed of a vessel would, however, be obviously inapplicable when she was approaching the observer, either directly, or at a very oblique angle.

Mr. Mallet observed, that the great improver of instruments of this kind was M. Porro, an officer of Engineers in the service of Piedmont, a detailed account of whose 'Instruments pour le levés des plans,' was given by M. H. de Senármont in the 'Annales des Mines,' 4th series, vol. xvi. (1849). An instrument for measuring distances was known at least 200 years ago, under the name of 'stadium,' and all subsequent improvements had been based on the same principle upon which that instrument had been constructed, namely, the similarity of the triangles formed inside the telescope by the image, and outside the telescope by the object itself. The results derivable from this class of instruments, in their simple form, could only be considered as approximations, and were chiefly available for such purposes as estimating the distance for rifle-shooting, &c. One peculiarity of the instruments constructed on the system of M. Porro, consisted in the micrometer net or scale, being so arranged, that the distance was at once read from the staff, and hence the necessity for tabular deduction was dispensed with. He had personally tested the degree of accuracy with which distances could be measured by M. Porro's instruments, and he had found, by comparison with trigonometrical measurements, that distances of 500 yards in length could be read off in favourable weather to within 3 inches or 4 inches. This result agreed closely with the results obtained by M. Porro, and M. de Senármont, who stated that in a distance of 800 metres the error did not exceed 2 centimètres. The correction necessary for the varying position of the focus was completely effected by M. Porro's method, and in careful hands his instrument was of great use in affording rapid approximations.

As regarded the instrument which had been exhibited by Mr. Adie, its power would necessarily be limited to distances not exceeding 400 yards or 500 yards, owing to the extreme difficulty of measuring the very small angles which were subtended at more remote distances. In Dr. Brinkley's investigations as to the measurement of the parallax of the fixed stars, that astronomer had found that when working with an eight-feet circle, and aided by all the appliances of a fixed observatory, no measurement of an angle of less than three seconds could be relied upon. Another element which would tend to vitiate the result at great distances, would be the personal equation of the observer. This relation expressed the difference which existed between the observing powers of different individuals.

Mr. GRAVATT said, that in the investigations made by Dr. Brinkley, the difference really turned on the coefficient of the refraction, and not on the measurement of the angle. As regarded the personal equation, the precise instant at which a given contact took place, would be differently estimated by a bold, and a timid man.

Mr. J. SCOTT RUSSELL remarked, that by disciplining the senses, the personal equation could to a great extent be eliminated. It might safely be asserted, that few men could determine with perfect precision an interval of time to the tenth part of a second. If any one would obtain a stop-watch, which would indicate that division of time, they would at first find that they failed to stop the hand at the intended instant, but by continual practice, they would on the one hand, get rid of the agitation which occasioned them to stop too late, and on the other hand, of the eagerness which made them stop too soon. In short, if they took the trouble thoroughly to educate themselves, they would observe with an amount of precision, which people who had not taken the same pains, would consider to be unattainable.

Mr. MALLET, in explanation of his previous remarks, would define the personal equation to be the average difference of accuracy derived from a great number of instances, between two, or more observers, in the record of a fact, or class of facts. No human observations could be absolutely accurate, and all records of observations must therefore be considered only as approximations. Observations might approximate nearer and nearer to the truth, but the relation between the residues left between the best approximations of separate observers, constituted the personal equation, a quantity which could not be wholly eliminated, or got rid of. In illustration, when assisted by his son, Dr. John Wm. Mallet, in making some experiments, as to the transit of a wave of impulse, analagous to an earthquake wave, through solids, such as rock formations, they found that the limit of instrumental error in the instruments employed, for the measurement of time (which could always be measured with much greater accuracy than space) was about the $\frac{1}{3000}$th part of a single second—a quantity easily ascertained from the reduction of a number of observations, but inappreciable by direct observation. The limit of direct observational power for time was about $\frac{1}{200}$th part of a second, and the comparison of his own personal equation with that of his son, showed that the latter was a sharper observer than he was, by about the $\frac{1}{2000}$th part of a second. These figures were given from memory, but they were sufficiently accurate to convey a general idea of his meaning.

Mr. C. B. LANE said, that thirteen years, or fourteen years ago, he fitted a Gravatt's level with an additional diaphragm plate and adjusting screws, for the purpose of measuring horizontal distances.

The additional plate was constructed, so as to slide vertically between a pair of grooves in the ordinary diaphragm plate, and by this means, a horizontal wire was adjusted in the same plane with, and parallel to, the ordinary central horizontal wire. The result of his experience of this mode of measuring distances, did not induce him to recommend, that it should be employed where great accuracy was required; but for trial sections, or analogous operations, and particularly for measuring distances over broken ground, he thought it gave more trustworthy results than the means usually employed in such cases.

December 3, 1861.

GEORGE PARKER BIDDER, President,
in the Chair.

The following Candidates were balloted for and duly elected:—JOHN GRANT, ROBERT JEFFREY, HAMILTON LEE SMITH, and ARTHUR WHITEHEAD, as Members; JAMES LEMPRIÈRE ANLEY, GEORGE PARKER BIDDER, Junior, CHARLES BILLSON, SIDENGHAM DUER, GEORGE HARDINGE, JAMES WILLIAM HAYNES, CAPTAIN HENRY HYDE, B.E., JOHN BIRCH PADDON, CHARLES SLAGG, FREDERICK GEORGE SLESSOR, and GEORGE KELSON STOTHERT, as Associates.

No. 1,046.—"On the Discharge from Under-Drainage, and its effect on the Arterial Channels and Outfalls of the Country."[1]

By JOHN BAILEY DENTON, M. Inst. C.E.

THE following remarks, on a series of experiments made at Hinxworth, in 1856-57, to ascertain the relative fall of rain on the surface and the discharge of water from the under-drains, over an area of several hundred acres of cultivated ground, in a central position of Great Britain, are brought forward, with a full conviction of their imperfect character, but with a belief that the deductions to be drawn from them will be found of some value, in considering the great objects of Arterial Drainage and Outfalls, for the improvement of which an Act of Parliament was passed during the last session.

It should be premised, that the results of the experiments themselves have been before tabulated and published, in the beginning of last year, in the "Journal of the Royal Agricultural Society."[2] The object of their publication then was, to show the farmers of wet lands how deep under-draining affected the soil, and they are now necessarily repeated, in order that the Members of the Institution may have the details, and be enabled to test the accuracy of the deductions.

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[1] The discussion upon this Paper extended over portions of four evenings, but an abstract of the whole is given consecutively.

[2] *Vide* "The Journal of the Royal Agricultural Society of England."—Vol. xx., pp. 273-294.

Before examining the particular experiments referred to, it will be desirable to make a few general remarks, on the nature and extent of the lands in Great Britain capable of improvement by drainage.

Taking a broad view of the lands requiring draining, they may be divided into two classes;—First. The surcharged free, or porous soils, and, secondly, the absorbent retentive soils, usually, though incorrectly, called, 'impervious clays.'

This simple classification is the more appropriate, in considering the mode in which under-draining will affect the trunk drainage of the country, as the 'free soils' are subject to natural though slow drainage, before they are artificially drained, by percolation from a higher to a lower level; the discharge from those soils being the springs which burst from the lower outcrops to feed the arterial channels; whereas the clay soils, in their undrained state, only release the water they absorb by evaporation; the little that is not evaporated oozing into the free soils and the porous rocks with which they are in contact.[1] The division of wet lands, under two characteristic heads, may also be justified by the rules practically recognized in the operation of under-drainage. The free soils are susceptible of drainage by deep drains, at wide and irregular distances; the number being governed by the depth of the drains, and their position by the form of the ground and any special condition of subsoil; and in these free soils, test-holes are the best index to successful and economical drainage. The clays, on the contrary, reject the theory of depth governing the interval between the drains; and although it is absolutely necessary to vary the position and parallelism of the drains, to agree with the various undulations and hollows of the ground, still the whole soil must be uniformly drained, and be thoroughly aërated, by frequent drains, to overcome as much as possible its retentive properties,—the number of the drains being governed by the amount of profit to be gained by the operation, and the use to which the land is to be applied. It is found that test-holes, in many descriptions of clays, are no criterion of the effect of under-drains, unless critically and minutely examined, and that they cannot be practically made the guide of operations, as they are in free soils. When once drained, the surcharged free soils partake of the same character as those which are naturally dry, and they are then equally capable of absorption and percolation; the only difference being the depth of the subterranean water-level, which, in the case of the higher chalk and the sand formations, sinks beyond the reach of evaporation, but in the case of drained lands, though lowered by the operation of draining, remains within reach. The clays, on the contrary, though rendered capable of rapid filtration by under-drainage, still possess their peculiar powers of retention and expansion, which limit their capabilities of absorption and cause them to resist, more or less according to the state of the surface, the admission of falling rain, as rapidly as the free soils. The 'free soils' which suffer from wetness, should be understood to include the drifted and alluvial beds, which cover the impervious older strata, as well as the outcrop of the water-bearing strata at their lower levels. Percolation and evaporation are ever more or less at work on these soils, and the breadth of injurious wetness is determined by the extent of land, the underwater of which is tributary to, and shows itself at, the saturated outcrop, and the inclination of the impervious base upon which the saturated soil rests. In local phrase, the wet free soils will include gravels, sands, peats, loams, and every description of mixed earth. Clays of different density will be found frequently mixed with these drifted free soils, and it is in dealing with these mixed soils that the judgment of the draining Engineer will best display itself. The 'clays' have as many local significations as the free soils; being called marls, loams, gaults, &c.,—but wherever any soils exist with a proportion of one-tenth of argillaceous matter in their constitution, they are found to require the aëration of uniform under-drainage.

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[1] This dual division of the soils of England was adopted in an old country distich, which exhibits a normal appreciation of drainage :—

> "When the Clays feed the Sand,
> Then it's good for Old England,
> But when the Sand feeds the Clay,
> Then she cries, Oh! lack a day."

The old rhymist evidently viewed the 'clays' in a friendly light, as possessing conservative powers, though he had not then become acquainted with Professor Johnston's opinion, that by deep drainage and steam cultivation, they "were destined to become the best wheat-growing lands in the kingdom."

The total extent of wet lands, drained, or capable of improvement by draining, in Great Britain, is estimated at 22,800,000 acres, out of the total area of 56,352,000 acres. The extent of land, already permanently drained, does not at the present time reach 1,500,000 acres; so that there remains undrained about 21,300,000 acres. The extent of the 'free soils' drained, or requiring draining, is about 12,000,000 acres, out of the 22,800,000, thus leaving about 10,800,000 acres of 'clays.' These figures are introduced to draw attention to the magnitude of the field to which under-drainage is gradually extending itself, and for which provision must be made, sooner or later, in the main arteries and outfalls.

In the particular instance now to be referred to, the experiments were made on an equal area of the two descriptions of land. The Hinxworth estate, the property of Mr. Clutterbuck, of Watford, who kindly permitted the experiments to be made, consists of three farms, containing about 800 acres. It lies at the bottom of the northern escarpment of the London basin, and covers a portion of the lowest bed of the chalk, the outcrop of the green-sand, and a portion of the gault of the green-sand formation. In several parts a superficial deposit of drifted mixed, or 'free' soil overlies the older beds. The layer of green-sand 'in situ' is very thin, and it was in draining through this bed that the coprolites, now being raised in such large quantities in the locality, were first found. The gault was remarkably stiff and tenacious, though impregnated with lime from its proximity to the chalk, a special condition which allowed the water, contrary to general experience, to preserve a level in the test-holes agreeing with that in the subsoil.

Analyses of the two descriptions of soil, made by Professor Way, showed that,

The 'free,' or mixed soil, was composed of

Moisture and organic matter . .	3·27
Sands and clays	24·37
Silica soluble in acids	1·23
Oxide of iron	1·14
Phosphate of lime	0·92
Sulphate of lime	0·76
Carbonate of lime	68·31
	100·00

The gault clay was composed of

Moisture and organic matter . .	5·01
Sands	0·66
Clay	63·26
Carbonate of lime	31·07
	100·00

The Tables (Appendix, pages 66 to 82 inclusive), give the daily record of the rainfall, of the discharge of water from the drains, of the height of the barometer and the thermometer, and of the temperature of the soil at 18 inches and 42 inches respectively below the surface.

It will be observed, that the experiments did not extend to the entire estate of 800 acres, but to certain fields containing about 100 acres, or one-eighth of the total quantity, in equal proportions of the two descriptions of soil; they afford, however, a fair criterion of the whole property, and represent a type of the land requiring systematic under-draining in Great Britain.

Although the whole estate was drained by one connected system of works, the mode of draining each description of soil was necessarily as different as the soils themselves. The 'free soils' were drained by occasional wide parallel drains, from 4 feet to 8 feet deep, at a cost varying from £1. 10*s*. to £3. 10*s*. per acre, and the number of drains was reduced to a minimum, on the principle that any excess of work beyond what was sufficient to remove injurious wetness would be a waste of outlay. The 'gault clay,' on the contrary, was drained uniformly by a parallel arrangement of drains 25 feet and 27 feet apart, and 4 feet deep, at a cost varying from £5. 10*s*. to £6. 10*s*. per acre, and the number of drains was increased to a maximum consistent with economy; the object being twofold, to remove excess of wetness, and to promote the aëration and disintegration of the soil, so as to counteract as much as possible its retentive properties.

The two systems of drainage, applicable to the two characteristic descriptions of soil, are represented in Plate 2, which is the map of an estate in the neighbourhood of Rugby. The number and position of the drains mark the different soils, without any other means of delineation.

It should be stated, as the result of observations reaching over many years, that the length of the discharging period of under-drains has been found to depend, not so much on the duration, and the quantity, of the rain falling during the immediate period of discharge, as on the wetness of the preceding seasons. If the preceding winter has been subject to an ordinary rainfall, and the summer has been dry, as in 1859, with evaporation active, the discharge of the main drains will commence late in the autumn; whereas if a wet winter is succeeded by a wet summer, like that of 1860, it is possible that the under-drains may not cease running during the whole year. Under ordinary meteorological and physical conditions, the under-drains of the 'free' soils will begin to discharge in the month of October, or the beginning of November, and those of the 'clays' in the end of November, or the beginning of December. This difference of time is, doubtless, due to the absorbent qualities of 'clays' which seize, and to their retentive powers, which hold, the first water which reaches their inner recesses—as will be presently seen, when treating of 'clay soils'—whereas the 'free soils,' not possessing the retentive property in anything like the same degree, allow any excess to pass away gradually, after the subterranean level has been regained. In a majority of instances, in which 'free soils' require under-draining, it is found that surrounding, or adjoining lands, of a higher level and of the same stratum, have a great influence upon the extent and continuance of wetness; and this fact regulates, more or less, the period of discharge. The under-water percolating the soil in a diffused, or general manner from a higher to a lower level,'[1] has much more effect on the under-drainage of land than is generally admitted. It is the omission to deal with and provide for it properly, that is the great cause of defective work, and of the dissatisfaction which is occasionally felt. In fact, in very much of the work already executed under government control, it has been considered a matter of supererogation to look beyond the four corners of the field to be drained, and to inquire into the real cause of its wetness, which is often beyond the field itself.

The period over which the Hinxworth experiments extended was from 1st October, 1856, to 31st May, 1857.

The rainfall in 1853 amounted to 24½ inches.
„ 1854 „ 19 „
„ 1855 „ $24\frac{6}{10}$ „
„ 1856 „ 23 „
„ 1857 „ 21½ „

The average rainfall in the district is 24 inches. It will be seen, therefore, that there had been no extraordinary fall of rain preceding the experiments. The tables also show, that no excessive fall marked the period selected for making these experiments, as the greatest fall in twenty-four hours was 0·542 of an inch; and that, whereas the average fall for the eight months from October to May inclusive is 13 inches, the actual fall at Hinxworth during the same months, when the experiments were made, was 10·045 inches.

Before under-draining the surcharged 'free soils' at Hinxworth, the subterranean water level, following the universal law of nature, gradually rose higher and higher, as it was replenished by the autumnal and the winter rains. As soon as the summer had passed, and evaporation and vegetation had slackened their demand for moisture, and had allowed a portion of the rainfall to descend to the subsoil, the water bed began to rise, and it continued rising until the soil became saturated to the surface; when the surface soil—the seed bed of the farmer—instead of being warm and genial for the first action of vegetable life, was chilled by evaporation, which had by that time again become active. In February the soil had generally become fully saturated, in accordance with the same law of Nature, which has given to that month the cognomen of 'February fill Dyke;' and from that time until the middle of the following month, the ground would remain saturated. In April the twofold action, of slow percolation downward, and rapid evaporation upward, would exceed the rainfall, and necessarily lower the water bed, and so allow vegetation, weakened by wet and cold, to struggle into growth. It was only when the 'free' soils were full to the surface, that the land springs broke from the slopes, rising higher and higher as replenishment took place; and it was at that time, also, that heavy and successive rains would flow over the surface to the outfalls, and add their quota to the freshets which would fill the valleys.

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[1] Designated by the Author in a former Paper 'the water of pressure,' in contradistinction to 'the water of springs,' which is defined to be such as travels in volume, constant, or intermittent, over, or through the soil.

Before under-draining the 'clays,' the effect of the autumn rains was to feed their absorbent and retentive properties, until the soil was completely saturated to the surface,[1] when the excess would either flow off by the land furrows, and by the slacks and hollows of the natural surface, or it would rest upon the ground, until it was dissipated by evaporation.

EFFECT OF UNDER-DRAINING THE FREE SOILS.—The effect of under-draining the 'free soils,' and in fact most of the mixed soils, will be readily understood, when it is observed, that no water can run from the under-drains until the water bed has been raised by descending rains to the level of the drains—which is not exactly the case in the 'clays'—and that as the surface springs rise higher and higher before draining, so the lowest drains will begin to run fast, and as soon as the water bed of the whole area drained, forming an inclined plane, has risen by degrees to the height of every drain, the whole system will be at work, and not till then. It should be borne in mind, that a portion of the infiltrated water—and not an inconsiderable one in some cases—is claimed by the space in the subsoil intermediate between the level of the drains, and the depth to which the water-bed may have sunk, after the drains have ceased to run in the spring. This space will be found to be more, or less, according to the height and the aspect, as influencing gravitation and evaporation, and the extent to which the disintegration of the subsoil by drainage may promote capillary attraction. The quantity discharged by the drains, therefore, does not represent the whole of the infiltrated water, which should be understood to include, first, the water discharged by the drains; secondly, the water which gravitates to the outcrop springs; and, thirdly, the moisture which returns upward from the subsoil beneath the drains, by attraction

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[1] The absorbent and retentive powers of 'clays' differ. The principal clays of England have been found, by careful experiments, to exhibit those qualities in the following comparative degrees:—

		Weight.	Expansion.
Oxford Clay	(Hunts)	342	340
Wealden Clay . . .	(Somerset). . . .	357	420
Lias Clay	(Vale of Belvoir) .	362	390
Warp Clay	(Somerset). . . .	400	215
Boulder (drift) Clay .	(Hunts).	506	600
New Red sand-stone Clay	(Warwick). . . .	520	430
London Clay . . .	(Middlesex) . . .	554	534

into the soil above them, to be dispersed by evaporation at the surface. In certain cases, where the surcharged lands approach the lowest outcrop, or lip of the stratum, or bed, the drains partake of the nature of perennial springs, and they continue to discharge the overflow of the subjacent water bed during all the year.

That the system of drains adopted at Hinxworth was effective, was shown by the test-holes dug midway between the drains. It will be seen, by the tables, that the outlets discharged water before the test-holes indicated that the water-bed had risen to the height of the drains; but this seeming contradiction to what has been stated, is explained by the fact, that the test-holes were not on the lowest ground, and that the drains below gathered water before the water had risen in the highest ground up to the drains.

By reference to columns 4 and 5 in the tables, however, it will be seen, that the water in the test holes fluctuated with the rainfall; and that though generally approximating in height with the level of the drains, it rose upon one occasion to within 1 foot 11 inches of the surface, sinking again to 4 feet within five days afterwards.

The quantity of water discharged by the under-drains from the 'free soil' was a very large proportion of the rain which fell during the period of discharge. The quantity of rain which fell on the surface was 10·045 inches, or 227,220 gallons per acre. The quantity of water discharged was a little more than 7 inches, or 160,550 gallons, which is more than two-thirds of the rain which fell on the surface. This proportion has reference only to the rainfall of the eight months, the discharging period during which the experiments were made. If the discharge of the twelve months be compared with the corresponding rainfall, it will be found to be less than one-third, arising from the fact, that while the discharge of the remaining four months was very trifling, the rainfall was about 11½ inches, or 260,153 gallons per acre. Again, the discharged quantity quoted in the foregoing passage has reference to one series of experiments only, that of a surcharged 'free soil.' If the series, having reference to a mixed soil, be added, and the mean discharge of the two be taken, it will be found that the discharge of the twelve months, as compared with the corresponding rainfall, will be nearly one-fourth. If this proportion be taken as representing the discharge by drainage from the 'free and mixed soils' of England,—and it may fairly be so taken,—then about 6 inches in depth, or 135,732 gallons per acre, will be the mean quantity of water discharged from such soils to the outfalls by under-draining. These proportions of discharged water, are not inconsistent with the experiments of Dickinson, Dalton, and Charnock. Dickinson showed,[1] that the quantity which descended beyond the reach of evaporation in the chalk was 11·294 inches, out of an average rainfall of 26·61 inches. Dalton stated,[1] that out of an average rainfall, for three years, of 33·560 inches, the discharged quantity was 8·397 inches, or one-fourth. Charnock, in his Holmfield experiments, showed,[2] that out of an average rainfall, for five years, of 24·60 inches, the discharged quantity was 4·85 inches, or one-fifth. These variations will be readily reconciled by the difference in the soils experimented upon, and the mode of making the experiments. The depth of 6 inches, given as the discharge from the drains, is, to a great extent, new water rescued from evaporation, and will 'pro tanto' swell the ordinary flow of rivers. If this discharge of 6 inches was gradually dispersed over the discharging period, the want of capacity in the arterial channels would probably not be manifested for many succeeding years. But the experiments at Hinxworth show, that the drains were considerably affected after every larger fall of rain; and this circumstance, considered in conjunction with the very largely augmented discharge from clays, as will be presently explained, renders the subject one of great moment.

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[1] *Vide* "The Journal of the Royal Agricultural Society of England."—Vol. v., p. 150.

On December 13th, after frequent rains for eight days previously, there was a fall of 0·452 of an inch in depth, equal to 10,225 gallons per acre; and the discharge from the drains of the 'free soils,' increased from 695 gallons per acre on the 12th, to 2,420 gallons on the 13th December. On January the 10th, after frequent rains for some days, there was a fall of rain of 0·542 of an inch, and the discharge was increased from 910 gallons on the 9th, to 1,945 gallons on the 10th January. These are maxima. By turning, however, to February, it will be found, that very little rain fell,—only 4,343 gallons per acre in the whole month,—and that the discharge of the month was 27,360 gallons, or nearly 1,000 gallons per diem per acre. The monthly rainfall and discharge from the 'free' and 'mixed' soils, reduced to an average daily quantity per acre, were as follows:—

	Rainfall.	Discharge.
October	1200 gall.	211 gall.
November	1229 „	484 „
December	901 „	678 „
January	1702 „	1337 „
February	155 „	744 „
March	598 „	262 „
April	1085 „	293 „
May	547 „	148 „

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[1] *Vide* "Memoirs of the Literary and Philosophical Society of Manchester."—Vol. v., p. 361.

[2] *Vide* "The Journal of the Royal Agricultural Society of England."—Vol. x., p. 516.

EFFECT OF UNDER-DRAINING THE CLAY SOILS. — It has already been stated, that the discharge from 'free soils' precedes that of 'clays' by a considerable time; and in tracing the discharge of the drains from the clays at Hinxworth after they have been drained, it is seen that they did not begin to discharge at all till the end of November. By that time the 3¼ inches of rain which had fallen in October and November, had just sufficed to fill the inner pores of the soil, and its more minute interstices. The tables show, that the drains began slightly to discharge on the 24th November, though the water had not risen to the height of the drains. On January 10th the soil was filled up to its capability of retention. On that day a fall of 0·542 of an inch, or 12,261 gallons per acre, took place, and a remarkable increase in the rate of discharge was the consequence. From a flow of 125 gallons per acre on the 9th of January, the outlets discharged 5,150 gallons on the 10th. In December, when it was observed that the soil was not full to the level of the drains, the fall of rain on the 13th of 0·452 of an inch, or 10,225 gallons per acre, did not affect the discharge in any great degree, the discharge on the 12th being 160 gallons per acre, and that on the 13th was 975 gallons, or six times the amount of the day before. In January the increase on the 10th was forty-fold. These figures represent the discharge from the clays only. The tables show, that as the character of the subsoil becomes more open and mixed, this sudden discharge becomes less. It is when, by repeated rains, the clays have had their peculiar property of retention fully satisfied, holding within them as much in their drained condition as they are capable of holding, that they are in that state which fits them to discharge the largest proportion of any subsequent rainfall in the shortest time. Any fresh rain taken in above must then force out an equal quantity of water below; and as under-drains are aërated conduits, and water is eight hundred and seventeen times heavier than air, it can readily be understood, that with a sufficient number of drains to overpower, as far as possible, retention, the displacement would be rapid.

The total quantity of water discharged annually by the clays is small compared with that discharged by the free soils. The Hinxworth experiments showed it to be only 59,931 gallons, or about 2½ inches per acre. If those 59,931 gallons were regularly dispersed over the discharging period, it would not materially affect the arterial system of the country. But as so large a proportion

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[1] Microscopic examination of the same clay before and after under-draining shows, that the texture is quite different, the action of water passing out beneath as well as evaporation continuing, though reduced, from the surface above producing a disintegration, which does not result from evaporation only.

of heavier rainfalls is immediately discharged, when the soil is saturated to the extent of its capability, and when the free soils will be discharging at least 1,000 gallons per acre per diem, and the rivers may be preoccupied by their natural supply, and by the waters that pass off the surface without entering it, another feature of importance presents itself.

The monthly rainfall and discharge from the 'clays' at Hinxworth, reduced to an average daily quantity per acre, were as follows:—

	Rainfall.	Discharge.
October	1200 gall.	Nil. gall.
November	1229 „	11 „
December	901 „	188 „
January	1702 „	1026 „
February	155 „	323 „
March	598 „	107 „
April	1085 „	206 „
May	547 „	110 „

This being the action of under-draining, its results will be;— first, to render the surface more capable of absorbing the rain that falls upon it; secondly, to lower the discharge of the upper surface springs in a slight degree; and, thirdly, to withdraw from the power of evaporation all the water which the under-drains discharge.

Upon the first result there can be no difference of opinion. That the voiding of water beneath, by drainage, gives the soil, from which the water is taken, an increased capacity for absorption, is obvious. And if all the drained land was deeply cultivated, there would be little, or no overflow from the land surface; for the space occupied by air and water in a well-stirred soil is represented by Dr. Madden[1] to be one-fourth of its depth, while that similarly occupied in a drained subsoil may be taken as one-twelfth. So that, supposing the land to be drained 4 feet deep, and the surface to be cultivated 10 inches deep, the clear capacity for the reception of rain would be 5½ inches vertical depth. Fortunate would be the owners of land, and the inhabitants of valleys, if this condition generally existed; for sudden rainfalls would then be stored in the land, and be afterwards discharged gradually, so that surface freshets would be almost unheard-of. But the configuration of the surface, and the use and cultivation of the land, all forbid this state of things being general. The slopes of the free soils are frequently steeper than those of the clays. The major portion of the free soils is in pasturage, and the arable land for the most part maintains a ridge and furrow surface, which, added to the natural hollows, are circumstances that must interfere with the complete absorption of which a drained soil is susceptible, and prevent any very sensible reduction of the floods. Freshets, from such circumstances, will still prevail, though, as the processes of steam cultivation and deeper ploughing become more general, a greater proportion of the rain will be admitted, and to a certain limited extent floods will be diminished.

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[1] *Vide* "Journal of the Royal Agricultural Society of England."

Upon the second result the deduction appears equally clear. If the object of under-draining the free soils is to lower the water bed, it is obvious that those minor, or intermittent springs which burst from the slopes, as the water bed is replenished, must follow that water bed and be lowered also. As it has been shown, however, by Mr. Charnock, in his Holmfield experiments,[1] that evaporation from an undrained soil, maintained in a state of saturation, will exceed the rainfall, while that from the same soil drained will be less, the effect of under-draining upon the main perennial springs which supply rivers is to increase their flow, and not to diminish it, as has been erroneously stated. This circumstance is of great advantage, when viewed in relation to the increasing pollution of rivers, by the discharge into them of town sewage. The fact that there can be no continued discharge from any drained land, until the water-bed has been raised to the level of the drains, leads to the assurance, that the main springs, fed by the overflow, or discharge of that water-bed, cannot be diminished by under-drainage, unless it were proved that the more minute division, or disintegration, resulting from draining would promote evaporation, and facilitate attraction, or suction from beneath the drains.

Mr. Charnock's experiments, however, clearly show, that whereas the evaporation from a saturated soil is 8 inches more than the rainfall, that from a drained soil is 5 inches less. Though this difference may not precisely show the effect of under-drainage, it cannot fail to convey to the mind a conclusion that a saving in favour of the arterial water supply is gained by under-draining. His experiments extended from 1842 to 1846 inclusive, and the quantity of rain which fell on the surface, and the quantities of water evaporated from a soil maintained in a state of saturation, and from a soil drained, were severally as follows:—

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[1] *Vide* "Journal of the Royal Agricultural Society of England." Vol. x., p. 516.

	Rain-fall. Inches.	Evaporation. From soil saturated. Inches.	Evaporation. From soil drained. Inches.
1842 . . .	26·11	30·02	21·56
1843 . . .	24·49	31·19	20·11
1844 . . .	19·00	37·85	15·40
1845 . . .	28·18	31·09	23·26
1846 . . .	25·24	33·28	18·38
5)	123·02	163·43	98·71
Mean	24·60	32·68	19·74

If these figures are to be relied upon, they show that in those cases, where from pressure of surrounding lands, or otherwise, a district is maintained in a state of saturation, similar to the soil experimented on by Mr. Charnock, and with an equal rainfall, an amount of evaporation of 8 inches more than the rainfall may be constant; whereas on the same land, when drained, the evaporation would be reduced to 5 inches less than the rainfall, making a difference of 13 inches of water rescued from the atmosphere in favour of the rivers.

These experiments, it should be repeated, are cited to show, that the result of under-draining is rather to increase than to diminish the water supply, and not to afford any positive quantitative data.

The beneficial effect upon the vegetation, of lowering the standing water bed during spring and early summer, when all vegetable life is in its most sensitive stage, cannot be overrated. One simple fact recorded in the Hinxworth experiments will show this. By comparing columns 17 and 18 with columns 20 and 21, it will be seen that, in the months of March, April, and May, the temperature of the drained land at 18 inches below the surface was almost invariably 2° Fahrenheit higher than the undrained land. At the same time, there was a varying difference between the air 9 inches above the surface and the soil beneath of from 16° lower on some days, to 10° higher on others. The difference of 2° in the temperature of the drained and undrained soil, is equivalent to the removal of the land from an ungenial height to the protection of a valley,—a difference which will be the better appreciated, when it is remembered, that the growth of vegetation does not become general in the spring until the temperature of the soil has risen to 45°.[1]

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[1] The influence of hygrometric changes in the drained sub-soil is shown in the Hinxworth records, by the increase in the discharges of the drains on the 6th of March and the 22nd of April, without any rainfall on the surface. When this increase was observed, the barometer was examined, and it was found that there had been a fall of the mercury, though there had been no fall of rain.

An instance, showing the evil of a shallow water-bed, may be mentioned. During the survey for the drainage of the Test valley, in 1852, a violent storm occurred, which blew down a great number of trees along the whole course of the valley. When thrown down the roots of the trees exposed a perfectly flat bottom. It was observed, that the roots of trees of the same character varied in depth; and, recourse being had to the spirit level, it was found that this difference of depth arose from the irregularities of the surface only, and that the bottoms of the several trees formed one line, or inclined plane, precisely agreeing with the water level throughout the length of the valley. This would show, that directly the roots touched the water bed they refused to enter it;[1] and that the soil of that valley, and of those of which it was a type, was maintained in a state of wetness very closely approaching complete saturation.

Upon the third result, when repeating that which is so manifest, viz., that the water which goes out of the land by the under-drains cannot go up into the air by evaporation, it should be observed, that although the atmosphere is thus robbed of an amount of moisture, which reduces its power to give rain in return, it is a matter of some consolation that this island is surrounded by the ocean, and that south-west winds bring from the surface of the Atlantic, a sufficient supply quite independently of evaporation from the land. Dr. Dalton has stated, as the result of his experiments, that the average quantity evaporated from a water surface in England is 44·43 inches; while Mr. Charnock shows it to be 35 inches at Holmfirth; both in excess of the rainfall, with the quantity of moisture precipitated as 'dew' added.

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[1] As this reference to the valley of the Test, in which a peaty soil prevails, may provoke some remarks, as to the advantage of lowering the water bed beyond a certain depth in peat, it is desirable to state, that the practice of deep under-draining is gaining ground every year in the fens of Cambridgeshire and Lincolnshire. It will not be inopportune to quote the following apposite statement of the able American agriculturist, Judge French, on this. point. It is published in his book on Farm Drainage (1859), pp. 10 and 11.

"An impression has heretofore prevailed, that peat lands would be too dry if the water was pumped out, so as to reduce the water table more than a foot or two below the surface; but this idea is now controverted.

'In July, 1857, in company with three of the best farmers in Lincolnshire, the writer visited the fens, and carefully examined the crops and drainage. We passed a day, or two with one of the proprietors, who gave us some information upon the point in question. He stated that in general, the occupants of this land entertain the idea, that the crops would be ruined by draining to the depth of 4 feet. So strongly was he impressed with the belief that a deeper drainage was desirable, that he had enclosed his own estates with separate embankments, and put up a steam engine, and pumped up the water to a depth of 4 feet, while from the land all around him it is pumped out only a foot and a half below the surface, though in summer it may fall sometimes lower. The crops on this land are astonishing. Our friends estimated that the wheat then growing and nearly ripe would yield 56 bushels to the acre. Although this was considered a very dry season, the crops on the land of our host, were fully equal to the best upon the fens.

"The soil upon that part of the fens is now a fine black loam of 12 or 18 inches deep, resting upon clay. Upon other portions, the soil is of various depth and character, resting sometimes upon the gravel. Attention is called to these facts, to show that the common impression that these lands will not bear deep drainage, is controverted among the occupants themselves, and may prove to be one of those errors which become traditional we hardly know how. Most peat meadows, in New England, when first relieved of stagnant water, are very light and springy. The soil is filled with acids, which require to be neutralised by an application of lime, or what is cheaper and equally effectual, by exposure to the atmosphere. These soils, when the water is suddenly drawn out of them, retain their bulk for a time, and are too porous and unsubstantial for cultivation. A season, or two will cure this evil in many cases. The soil will become more compact and will often settle down many inches."

If these deductions were applied to the whole extent of the wet soils in Great Britain, the result would be startling; but inasmuch as it will take a great many years to complete the under-drainage of the country, it would answer no good purpose to go into that question. It will suffice to state, that supposing every acre of surcharged free soil to be drained, and the discharge on any particular day, when the land is saturated to the extent of its capability, to be the same as was shown by the free soils of Hinxworth on the 10th of January, 1857 (when there was only an ordinary fall of rain of half an inch), every 80 acres, discharging its drainage-water into the catchment basement of any particular river would place one acre under 10 inches of water, supposing the river itself to be full, and the land below to be saturated; and under the same circumstances 44 acres of clay land drainage would produce the same effect.

The recent publication of the Report on the salmon fisheries, with the plan of the catchment basins of the rivers of England and Wales, affords the means of illustrating this effect, in a tangible manner and in its true dimensions. Taking the catchment basin of the Trent, for instance, it is found by the plan referred to, that the contributing area (including the Derwent Basin) is 3,972 square miles, or 2,542,080 acres; and that the length of the main river and its tributaries, from the sources of Mow Cop and Swaine Greave to the Humber, is 562¾ miles.

By an examination of the soils of Great Britain, made by the Author some few years back, with a view to show the extent of wet land in the several counties of Great Britain, it was approximately ascertained, that there were 1,450,000 acres of land capable of improvement by draining, or which had already been drained, within the catchment basin of the Trent and the Derwent; and that of this quantity 900,000 acres were of a 'free and mixed soil,' requiring occasional and wide drainage, and 550,000 acres of the 'clay' denomination, requiring close parallel drainage. Multiplying these 900,000 acres of wet free soil by the quantity discharged from each acre of free soil, at Hinxworth, on the 10th

January, when ·542 of an inch of rain fell, there would be discharged into the valley sufficient water to cover more than 7,700 acres of land 10 inches deep;—and applying the same test to the clays, *one* day's drainage-water, thrown into the valleys from the under-*drains*, would be sufficient to cover nearly 13,000 acres with water 10 inches deep; so that a fall of rain of half an inch, under the circumstances referred to, would flood above 20,700 acres in one valley alone.

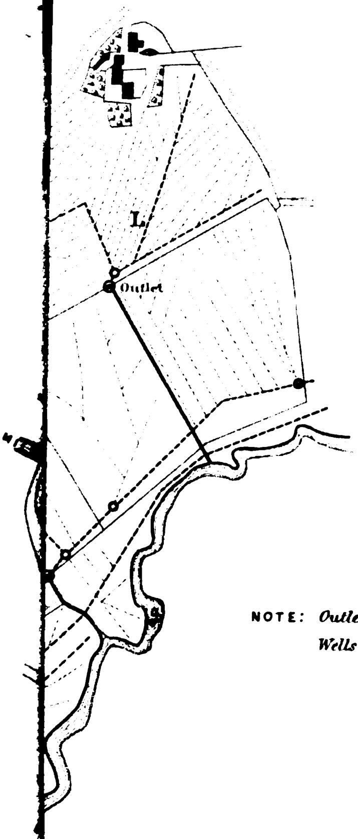
It is hoped that sufficient has been advanced to show, that the tendency of under-draining, as at present progressing, is to augment the ordinary flow of rivers at that period of the year when the soil is saturated to the extent of its capability, and that the time is not far distant, when the subject of this Paper will force itself upon the attention of the country.

For the first time, powers have been obtained by the Act of last session (Land Drainage Act, 1861), to enable the proprietors of lower lands, to remove mills, dams, weirs, and other impediments, which at present obstruct the upland waters, in their passage to the main outfalls, upon the payment of due compensation. The proprietors of two-thirds in extent of any injured district may oblige the proprietors of the remaining one-third to join in the expense of getting rid of those obstructions; and where it is necessary to straighten and to deepen old rivers, or watercourses, and to make new cuts, compulsory powers of purchasing land are given. These are the main provisions of the Act, and they can be put in force in any district duly constituted under the Act, or by a provisional order of the Inclosure Commissioners, if confirmed by a sessional Act of Parliament, similar to those annually passed to confirm the inclosure of commons. To possess legal facilities to remove and to alter mill dams and weirs, does not involve the country in any actual reduction of mill power, in the aggregate. On the contrary, it is believed that the effect of under-draining is to rescue from the atmosphere a large share of the rainfall, which will be available to increase, rather than to diminish, the water supply; and it will be found, when the time arrives for dealing with obstructed rivers, that in a vast majority of cases, the point aimed at will not be the destruction of the mill, but the means of discharge into the mill-tail; and that many of the valleys will be divided into a series of smaller areas, feeding each other with increased water supply, by the very process of draining. Moreover, past experience would indicate, that those impediments (when their owners become compliant under the powers of the important Act just obtained) will be frequently rendered of use to agriculture, by affording a ready means of irrigating low lands and of increasing motive power. The Act is divided into three parts:—Parts 1 and 2 refer to district drainages requiring combined works; and the extensive powers referred to are set forth in seventy-one clauses, among which are several provisions of a new and highly practical character. Part 3, refers chiefly to outfall works to be carried out by private owners, such as easements for the passage of drainage water through the lands of lower owners, and the deepening and straightening of watercourses. The means of obtaining these advantages, however, are attended with such heavy expense,—greater, in fact, than attended the exercise of the same powers as they partially existed before,—that this part of the Act is not likely to be used until it is amended.

The Paper is illustrated by a series of diagrams, from which Plate 2 has been compiled, and by the Tabular matter which is given in the Appendix.

PLATE 2. VOL. XXI.

RIPTIONS OF SOIL.



NOTE: *Outlets* ●

Wells covered ○

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APPENDIX.

HINXWORTH DRAINAGE.—MONTHLY RECORDS FROM 1ST OCTOBER,

	1	2	3	4	5	6	7	8	9
	RAINFALL.		BAROMETER.	OCCASIONAL DRAINAGE. Fields Nos. 18, 19, 20.—46 Acres. Soil, lower Chalk mixed with Clay, Gravel, and Sand. Green Sand is found mixed with Gault Clay. Also Coprolites. Very wet before Draining. Nos. 19 and 20 only, containing 25 Acres, Drained at this time.				PART OCCASIONAL AND PART WIDE PARALLEL DRAINAGE. 18 Acres. — Soil, same as last in part of field, remainder Gault and Gravel mixed.	
				Observations on Test Holes, being the depth of free soil from surface of Land to surface of Water in the Holes, which are sunk midway between the occasional Drains. Holes 6 feet deep.		Quantity of Water from Outlet No. 7, which discharges the Drain Water from 18, 19, and 20. Size of Pipe, 8 inches. Commenced running October 1.		Quantity of Water from Outlet No. 9, which discharges the Drain Water from No. 22. Size of Pipe, 5 inches. Commenced running October 12.	
Day of the Month.	Per Diem. Inches dec.	Per Acre. (Per Diem.) In Gallons.	Height at the time of recording the Discharge from the Outlets, 8 o'clock, A.M. *Note.*—It should be observed that the height recorded is simply the height of the mercury at a certain time of day.	Higher Side. Distance from Drain to Drain 59 yds. Depth of Drains 4 ft. 11 in.	Lower Side. Distance from Drain to Drain 57 yds. Depth of Drains 4 ft. 4 in.	Per Minute. In Gallons.	Per Acre. In Gallons (per diem).	Per Minute. In Gallons.	Per Acre. In Gallons (per diem).
1	..	..	No record of the changes of the barometer made before 21st October, 1856.	5 11	5 4	1¼	75	Nil.	Nil.
2	..	..		5 10	5 3	1¾	105	..	..
3	..	..		5 9	5 2	1⅜	80	..	..
4	·105	2,375		5 8	5 0	1½	90	..	..
5	·200	4,525		5 6	4 10	2	120	..	..
6	·060	1,355		5 3½	4 8	1⅜	80	..	..
7	·080	1,810		5 2	4 5	2	120	..	..
8	·185	4,185		5 0	4 3½	2⅝	160	..	..
9	·040	905		4 10	4 2	4	235	..	..
10	·060	1,355		4 9	4 1	6¼	360	..	..
11	·195	4,410		4 8	3 11	9	530	..	..
12	·415	9,390		4 6	3 7	27½	1,585	1–4th	20
13	·005	115		4 5	3 8	24	1,410	1–4	20
14	..	..		4 4	3 9	19½	1,115	1–8	10
15	·115	2,600		4 4½	3 9½	15	880	1–8	10
16	·070	1,585		4 5	3 10	10½	605	1–8	10
17	·100	2,260		4 5½	4 0	10	580	1–8	10
18	·005	115		4 6	4 2	9	530	1–8	10
19	..	..		4 6½	4 2	8½	495	1–8	10
20	..	..		4 7	4 2	8	470	1–8	10
21	..	..	30·12	4 7	4 2	8	470	1–9	9
22	..	..	30·28	4 7½	4 2½	7	400	1–9	9
23	..	..	30·26	4 8	4 3	6½	375	1–10	8
24	..	..	30·38	4 8½	4 3	6	350	1–12	7
25	..	..	30·40	4 9	4 3	6	350	1–16	5
26	..	..	30·39	4 9	4 3	5	285	1–16	5
27	..	..	30·36	4 9½	4 3	4¼	250	1–16	5
28	·002	45	30·28	4 10	4 3	4	235	1–16	5
29	·003	70	30·20	4 10	4 3	3¾	220	1–16	5
30	..	..	30·10	4 10	4 3	3	175	1–16	5
31	·005	115	30·05	4 10	4 3	3	175	1–16	5
Total	1·645	37,215		Total quantity of Water per Acre discharged			12,910	..	178
				Remainder unaccounted for			24,305	..	37,037
				Total Rainfall ..			37,215	..	37,215

1856, to 31st May, 1857.—Record for October, 1856.

10	11	12	13	14	15	16	17	18	19	20	21	22
Parallel Drainage. Fields 13 and part 14.—24 Acres. Soil, Gault Clay, with Lime infiltrated. Patches and veins of Sand found giving vent to Underwater which has run through the Summer of 1856.		Close Parallel Drainage. Fields Nos. 31, 32, and 33.—Nos. 31 and 32 only drained. 29 Acres. No. 33 undrained. Soil, Gault Clay, with Lime infiltrated. Considered very stiff and impenetrable. Drains, 25 feet apart, and 4 feet deep.					Temperature. At half-past Seven, A.M.					
Quantity of Water from Outlet No. 13, which discharges the Drain Water from Nos. 13 and part 14. Size of Pipe, 5 inches. Has run throughout the year.		Observations on Test Holes, being the depth of free soil from surface of Land to surface of Water in the Holes, which are sunk midway between the Drains. (See also Temperature.) Holes dug 5 feet deep.			Quantity of Water from Outlet No. 15, which discharges the Drain Water from Nos. 31 and 32. Size of Pipe, 7 inches. Commenced running Nov. 27.		Undrained Land.			Drained Land.		
		Drained Land.										
Per Minute. In Gallons.	Per Acre. In Gallons (per diem).	Higher Side. 25 ft. apart and 4 ft. deep. No. 31.	Lower Side. 25 ft. apart. and 4 ft. deep. No. 31.	Undrained Land No. 33.	Per Minute. In Gallons.	Per Acre. In Gallons (per diem).	Of Air 9 in. above surface. No. 33.	Of Soil 18 in. below ground. No. 33.	Of Soil 42 in. below ground. No. 33.	Of Air 9 in. above surface. No. 31.	Of Soil 18 in. below ground. No. 31.	Of Soil 42 in. below ground. No. 31.
1¼	75	Nil.	Nil.	No observations made this month.	Nil.	Nil.	No observations made this Month on the Temperature of the Soil.					
1¼	75	Nil.	Nil.		..	..						
1¼	75	4 9½	4 9		..	..						
1¼	75	4 9½	4 9		..	..						
1¼	75	4 9	4 8½		..	..						
1⅓	80	4 8½	4 8		..	..						
1¾	105	4 9	4 8½		..	..						
19⅓	1,160	4 10	4 9¾		..	..						
6¾	405	4 10½	4 10		..	..						
6¾	405	4 11	4 10½		..	..						
6½	390	4 11½	4 11		..	..						
30	1,800	4 10½	4 10		..	..						
8⅓	490	4 11	4 11		..	..						
3½	210	Nil.	Nil.		..	..						
4	235	..	..		..	..						
6	360	..	..		..	..						
6	360	..	..		..	..						
7	420	..	..		..	..						
6	350	..	..		..	..						
4	235	..	..		..	..						
3½	210	..	..		..	..						
3¼	195	..	..		..	..						
3	180	..	..		..	..						
3	180	..	..		..	..						
2¾	165	..	..		..	..						
2½	150	..	..		..	..						
2⅓	140	..	..		..	..						
2⅙	130	..	..		..	..						
2	120	..	..		..	..						
2	120	..	..		..	..						
1¾	105	..	..		..	..						
..	9,075	..	..	..	..	..						
..	28,140	..	..	..	..	37,215						
..	37,215	..	..	..	..	37,215						

HINXWORTH DRAINAGE.—RECORD

	1	2	3	4	5	6	7	8	9
	RAINFALL.		BAROMETER.	OCCASIONAL DRAINAGE. Fields Nos. 18, 19, 20.—46 Acres. Soil, lower Chalk mixed with Clay, Gravel, and Sand. Green Sand is found mixed with Gault Clay. Also Coprolites. Very wet before draining. Nos. 19 and 20 only drained up to Nov. 10, when the draining of No. 18 was commenced. It was finished Nov. 29.				PART OCCASIONAL AND PART WIDE PARALLEL DRAINAGE. 18 Acres. — Soil, same as last in part of field, remainder Gault and Gravel mixed.	
				Observations on Test Holes, being the depth of free soil from surface of Land to surface of Water in the Holes, which are sunk midway between the occasional Drains. Holes 6 feet deep.		Quantity of Water from Outlet No. 7, which discharges the Drain Water from 18, 19, and 20. Size of Pipe, 8 in. Commenced running October 1.		Quantity of Water from Outlet No. 9, which discharges the Drain Water from No. 22. Size of Pipe, 5 inches. Commenced running October 12.	
Day of the Month.	Per diem. Inches dec.	Per Acre. (Per Diem.) In Gallons.	Height at the time of recording the Discharge from the Outlets, 8 o'clock, A.M. *Note.*—It should be observed that the height recorded is simply the height of the mercury at a certain time of day.	Higher Side. Distance from Drain to Drain 59 yds. Depth of Drains 4 ft. 11 in.	Lower Side. Distance from Drain to Drain 57 yds. Depth of Drains 4 ft. 4 in.	Per Minute. In Gallons.	Per Acre. In Gallons (per diem).	Per Minute. In Gallons.	Per Acre. In Gallons (per diem).
1	·312	7,058	30·28	4 10	4 3	9½	555	1-8	10
2	·003	68	30·29	4 10	4 3	5	285	1 9	9
3	..	..	30·19	4 10	4 3	3	175	1-10	8
4	..	..	30·18	4 10	4 3	3	175	1-10	8
5	..	..	30·30	4 10	4 3	3	175	1-10	8
6	..	..	30·40	4 10	4 3	3	175	1-10	8
7	·005	113	30·50	4 10	4 3	3	175	1-10	8
8	..	..	30·37	4 19	4 3	3	175	1-10	8
9	·355	8,030	30·06	4 10	4 3	12	700	2-3	50
10	·005	113	29·50	4 10	4 3	5½	Field No. 18 being drained and added to this outlet, the daily measurements were only approximately taken.	3-8	30
11	..	..	29·30	4 10	4 3	5		3-8	30
12	·215	4,864	29·60	4 9	4 3	6⅞		1-2	40
13	·002	45	29·70	4 9	4 3	7		1-2	40
14	·003	68	29·79	4 9	4 3	7½		3-8	30
15	..	..	29·80	4 9	4 3	7½		3-8	30
16	..	..	30·10	4 9	4 3	8		1-4	20
17	..	..	30·10	4 9	4 3	9		1-4	20
18	·040	905	30·00	4 9	4 3	9		1-4	20
19	·072	1 628	30·04	4 9	4 3	12½		1-3	25
20	·053	1,199	20·09	4 9	4 3	15		1-2	40
21	·005	113	30·15	4 9	4 3	15¾		1-2	40
22	..	..	30·17	4 9	4 3	16		1-3	25
23	..	..	29·70	4 9	4 3	16		1-3	30
24	..	..	29·60	4 9	4 3	17		1-3	25
25	..	..	29·50	4 9	4 3	17		1-3	30
26	·015	339	29·60	4 9	4 2½	17¾		1-3	25
27	·540	12,216	29·58	4 8	4 2	33		11¼	900
28	·005	113	29·68	4 7	4 0	34½		3	240
29	..	..	29·68	4 7½	4 1	32		2	160
30	..	..	29·69	4 7½	4 1	30		2	160
Total	1·630 1·645	36,872 37,215		Total quantity of Water per Acre discharged			27,000	..	2,077
				Remainder unaccounted for			9,872	..	34,795
	3·275	74,087		Total Rainfall ..			36,872	..	36,872

OF THE MONTH OF NOVEMBER, 1856.

10	11	12	13	14	15	16	17	18	19	20	21	22
PARALLEL DRAINAGE.		CLOSE PARALLEL DRAINAGE.					TEMPERATURE.					
Fields 13 and part 14.—24 Acres. Soil, Gault Clay, with Lime infiltrated. Patches and Veins of Sand found giving vent to Under-water which has run through the Summer of 1856.		Fields Nos. 31, 32, and 33. Nos. 31 and 32 only drained.—29 Acres. No. 33 undrained. Soil, Gault Clay, with Lime infiltrated. Considered very stiff and impenetrable. Drains, 25 feet apart, and 4 feet deep.					At half-past Seven, A.M.					
							Undrained Land.			Drained Land.		
Quantity of water from Outlet No. 13, which discharges the Drain Water from Nos. 13 and part 14. Size of Pipe, 5 inches. Has run throughout the year.		Observations on Test Holes, being the depth of free soil from surface of Land to surface of water in the Holes, which are sunk midway between the Drains. (See also Temperature.) Test holes 5 feet deep.			Quantity of Water from Outlet No. 15, which discharges the Drain Water from Nos. 31 and 32. Size of Pipe 7 inches. Commenced running Nov. 27.		Of Air 9 in. above surface. No. 33.	Of Soil 18 in. below ground. No. 33.	Of Soil 42 in. below ground. No. 33.	Of Air 9 in. above surface. No. 31.	Of Soil 18 in. below ground. No. 31.	Of Soil 42 in. below ground. No. 31.
		Drained Land.										
Per Minute. In Gallons.	Per Acre. In Gallons (per diem).	Higher Side. 25 ft. apart and 4 ft. deep. No. 31.	Lower Side. 25 ft. apart and 4 ft. deep. No. 31.	Un-drained Land No. 33.	Per Minute. In Gallons.	Per Acre. In Gallons (per diem).						
2¾	165	Nil.	Nil.	No observations made prior to November 27.	Nil.	Nil.	No observations made this Month on the Temperature of the Soil.					
1¾	105	..	..		..	..						
1½	90	..	..		..	..						
1¼	75	..	..		..	..						
1	60	..	..		..	..						
1	60	..	..		..	..						
1	60	..	..		..	..						
1½	90	..	..		..	..						
6	360	..	..		..	..						
5½	330	..	..		..	..						
5½	330	..	..		..	..						
5½	330	..	..		..	..						
5	300	..	..		..	..						
4¾	285	..	..		..	..						
4¾	285	..	..		..	..						
3½	210	..	..		..	..						
2½	150	..	..		..	..						
2¼	135	..	..		..	..						
2¼	135	..	..		..	..						
2¼	135	..	..		..	..						
2¼	135	..	..		..	..						
2¼	135	..	..		..	..						
2¼	135	..	..		..	..						
2¼	135	..	..		..	..						
2¼	135	..	..		..	..						
3¼	195	..	..		..	..						
12¼	735	4 11	4 11	3 0	2¾	135						
5	300	4 11½	4 11½	2 10	1¼	65						
4	240	..	..	2 10	1¼	65						
3	180	..	..	2 9½	1¼	65						
..	6,015	..	..	..	..	330						
..	30,857	..	..	..	..	36,542						
..	36,872	..	..	..	..	36,872						

HINXWORTH DRAINAGE.—RECORD

Day of the Month.	1	2	3	4	5	6	7	8	9
	RAINFALL.		BAROMETER.	OCCASIONAL DRAINAGE.				PART OCCASIONAL AND PART WIDE PARALLEL DRAINAGE.	
				Fields Nos. 18, 19, 20.—46 Acres. Soil, lower Chalk mixed with Clay, Gravel, and Sand. Green Sand is found mixed with Gault Clay. Also Coprolites. Very wet before Draining.				18 Acres. — Soil, same as last in part of field, remainder Gault and Gravel mixed.	
				Observations on Test Holes, being the depth of free soil from surface of Land to surface of Water in the Holes, which are sunk midway between the occasional Drains. Test Holes 6 feet deep.		Quantity of Water from Outlet No. 7, which discharges the Drain Water from 18, 19, and 20. Size of Pipe, 8 inches. Commenced running October 1.		Quantity of Water from Outlet No. 9, which discharges the Drain Water from No. 22. Size of Pipe, 5 inches. Commenced running October 12.	
	Per Diem. Inches dec.	Per Acre. (Per Diem.) In Gallons.	Height at the time of recording the Discharge from the Outlets, 8 o'clock, A.M. *Note.*—It should be observed that the height recorded is simply the height of the mercury at a certain time of day.	Higher Side. Distance from Drain to Drain 59 yds. Depth of Drains 4 ft. 11 in.	Lower Side. Distance from Drain to Drain 57 yds. Depth of Drains 4 ft. 4 in.	Per Minute. In Gallons.	Per Acre. In Gallons (per diem).	Per Minute. In Gallons.	Per Acre. In Gallons (per diem).
1	..	..	29·80	4 8	4 1	28½	895	1½	120
2	..	..	29·80	4 8	4 1	25	780	1¾	140
3	..	..	29·69	4 8	4 1½	22½	695	1⅞	150
4	..	..	29·90	4 8	4 1½	20	620	1⅞	150
5	·073	1,651	29·59	4 8	4 1½	25½	795	1⅞	150
6	·027	610	29·40	4 8	4 1½	24½	755	1⅞	150
7	·050	1,131	29·49	4 8	4 1½	25½	795	2	160
8	..	..	29·49	4 8	4 1½	24½	755	2¼	180
9	·080	1,810	29·40	4 8	4 1½	27	830	3	240
10	·060	1,357	29·30	4 8	4 1½	26¼	820	3	240
11	·075	1,696	29·40	4 8	4 1½	24	745	6	480
12	·085	1,923	29·27	4 8	4 1½	22½	695	8	640
13	·452	10,225	28·89	3 8	2 11	77½	2,420	19	1,520
14	·023	520	29·40	3 10	3 0	55	1,715	10	800
15	..	..	30·20	3 10	3 2	47½	1,485	6	480
16	..	..	30·49	4 0	3 7	47½	1,485	6	480
17	..	..	30·37	4 1½	4 0	46¾	1,455	6	480
18	..	..	29·80	4 0	4 0½	40	1,245	5⅜	450
19	·100	2,262	30·30	4 2	4 2	34¼	1,085	6⅞	550
20	·005	113	30·38	4 2	4 2	37	1,145	6½	520
21	..	..	30·39	4 2	4 2	35	1,095	5¾	460
22	..	..	30·00	4 2½	4 2½	33	1,030	5¼	420
23	..	..	29·90	4 4	4 4	33	1,030	4⅞	395
24	·045	1,018	29·40	4 3	4 3	35	1,095	4¾	380
25	..	..	28·80	4 5	4 5	30	935	4½	360
26	..	..	28·70	4 6	4 6	26¼	820	4¼	340
27	..	..	29·19	4 6	4 6	21	660	3½	280
28	..	..	29·46	4 6½	4 6½	19	595	3	240
29	..	..	29·80	4 7	4 7	15¼	475	2¼	180
30	·150	3,393	30·10	4 6	4 6	19	595	5	400
31	·010	226	30·14	4 6½	4 2	18¾	590	4½	360
Total	1·235	27,935		Total quantity of Water per Acre discharged			30,135	..	11,895
				Rainfall			27,935	Difference unaccounted for.	16,040
				Excess discharged from Soil			2,630	Rainfall	27,935

OF THE MONTH OF DECEMBER, 1856.

10	11	12	13	14	15	16	17	18	19	20	21	22
PARALLEL DRAINAGE.		CLOSE PARALLEL DRAINAGE.					TEMPERATURE.					
Fields 13 and part 14.—24 Acres.—Soil, Gault Clay, with Lime infiltrated. Patches and veins of Sand found giving vent to Under-water which has run through the Summer of 1856.		Fields Nos. 31, 32, and 33.—Nos. 31 and 32 only drained. 29 Acres. No. 33 undrained. Soil, Gault Clay, with Lime infiltrated. Considered very stiff and impenetrable. Drains, 25 feet apart, and 4 feet deep.					At half-past Seven, A.M.					
							Undrained Land.			Drained Land.		
Quantity of Water from Outlet No. 13, which discharges the Drain Water from Nos. 13 and part 14. Size of Pipe, 5 inches. Has run throughout the year.		Observations on Test Holes, being the depth of free soil from surface of Land to surface of Water in the Holes, which are sunk midway between the Drains. Test Holes dug 5 feet deep.			Quantity of Water from Outlet No. 15, which discharges the Drain Water from Nos. 31 and 32. Size of Pipe, 7 inches. Commenced running Nov. 27.		Of Air 9 in. above surface. No. 33.	Of Soil 18 in. below ground. No. 33.	Of Soil 42 in. below ground. No 33.	Of Air 9 in. above surface. No. 31.	Of Soil 18 in. below ground. No. 31.	Of Soil 42 in. below ground. No. 31.
		Drained Land.										
Per Minute. In Gallons.	Per Acre. In Gallons (per diem).	Higher Side. 25 ft. apart and 4 ft. deep. No. 31.	Lower Side. 25 ft. apart and 4 ft. deep. No. 31.	Un-drained Land No. 33.	Per Minute. In Gallons.	Per Acre. In Gallons (per diem).						
4⅞	295	Nil.	Nil.	2 9	1¼	65	No observations made this Month on the Temperature of the Soil.					
3½	210	..	..	2 7	1⅛	55						
2¼	135	..	..	2 6	⅝	30						
2	120	..	..	2 6	⅝	30						
3⅜	200	..	..	2 5	¾	40						
3⅜	200	..	..	2 5½	¾	40						
4	235	..	..	2 5	⅞	45						
4¾	285	..	..	2 4½	⅞	45						
5	300	..	..	2 4	⅞	45						
5¼	315	4 11½	4 11	2 4	1	50						
15	900	4 11	4 11	2 4	2	100						
22½	1,350	4 10½	4 10	2 3½	3⅛	160						
47½	2,850	4 9	4 9	6	19½	975						
25	1,500	4 9	4 8	7	15	750						
15¾	945	4 9	4 8	7	13½	675						
10½	630	4 9	4 8	10	7½	375						
9	540	4 9	4 8	10½	8¼	415						
6¾	405	4 9	4 8	11	3¾	185						
8	480	4 9	4 8	1 0	4½	225						
7½	450	4 9	4 8	1 1	3⅛	160						
7½	450	4 9	4 8	1 1	3	150						
7½	450	4 9	4 9	1 2	2½	125						
7½	450	4 8	4 9	1 4	2¼	110						
7	420	4 8	4 9	1 4	2	100						
6	360	4 8	4 10	1 4	2	100						
5¼	315	4 8	4 10	1 4	1⅞	95						
4	235	4 9	4 10	1 4	1¼	65						
3	180	4 9	4 10	1 4	1	50						
2⅝	160	4 9	4 10	1 4	¾	40						
6½	390	4 7	4 9	1 3	6	300						
5⅝	340	4 6½	4 9	1 3	4½	225						
..	16,095	..	..	..	..	5,825						
..	11,840	..	..	..	..	22,110						
..	27,935	..	..	..	..	27,935						

HINXWORTH DRAINAGE.—RECORD

	1	2	3	4	5	6	7	8	9
	RAINFALL.		BAROMETER.	OCCASIONAL DRAINAGE.				PART OCCASIONAL AND PART WIDE PARALLEL DRAINAGE.	
				Fields Nos. 18, 19, 20.—46 Acres. Soil, lower Chalk mixed with Clay, Gravel, and Sand. Green Sand is found mixed with Gault Clay. Also Coprolites. Very wet before Draining.				Field No. 22. 18 Acr. Soil, same as last in part of field, remainder Gault and Gravel mixed.	
				Observations on Test Holes, being the depth of free soil from surface of Land to surface of Water in the Holes, which are sunk midway between the occasional Drains. Test Holes 6 feet deep.		Quantity of Water from Outlet No. 7, which discharges the Drain Water from 18, 19, and 20. Size of Pipe, 8 inches. Commenced running October 1.		Quantity of Water from Outlet No. 9, which discharges the Drain Water from No. 22. Size of Pipe, 5 inches. Commenced running October 12.	
Day of the Month.	Per Diem. Inches dec.	Per Acre. (Per Diem.) In Gallons.	Height at the time of recording the Discharge from the Outlets, 8 o'clock, A.M. *Note.*—It should be observed that the height recorded is simply the height of the mercury at a certain time of day.	Higher Side. Distance from Drain to Drain 59 yds. Depth of Drains 4 ft. 11 in.	Lower Side. Distance from Drain to Drain 57 yds. Depth of Drains 4 ft. 4 in.	Per Minute. In Gallons.	Per Acre. In Gallons (per diem).	Per Minute. In Gallons.	Per Acre. In Gallons (per diem).
1	·005	113	30·30	4 6	4 2	16	500	2½	200
2	·020	452	29·48	4 6	4 2	21	660	3¾	300
3	·042	950	29·20	4 6	4 2	24	750	5	400
4	·151	3,416	29·07	4 6	4 1	29	900	14½	1,150
5	·162	3,665	29·64	4 6	4 1	31	980	15¾	1,260
6	..	..	30·09	4 5½	4 0½	30	930	11¼	900
7	..	..	30·20	4 5	4 0	31½	995	7¼	580
8	..	..	30·24	4 5	4 1	28½	895	5¼	420
9	·035	792	30·13	4 4½	4 0	29	910	5	400
10	·542	12,261	29·46	3 5	2 8	62	1,945	45	3,600
11	·300	6,787	28·80	3 0	2 2	57½	1,800	40	3,200
12	·162	3.665	29·19	2 1	1 11	53¾	1,680	30¾	2,460
13	..	..	29·39	2 7	2 5	55	1,720	22½	1,800
14	..	..	29·80	3 2	2 11	55	1,720	12¾	1,020
15	..	..	29·90	3 6	3 3	50	1,560	9	720
16	·135	3,054	29·90	3 10	3 8	52½	1,640	9¾	780
17	..	..	30·20	4 1½	4 0	51½	1,605	9	720
18	·005	113	30·19	4 2	4 0	48	1,500	9	720
19	·005	113	30·17	4 3½	4 1	45	1,395	9	720
20	..	..	29·69	4 3	3 11½	43¾	1,350	9¾	780
21	·065	1,470	29·40	4 2	3 11	50	1,560	16½	1,320
22	·120	2,714	29·69	4 1	3 10	52½	1,640	17¼	1,380
23	·062	1,402	29·28	4 0½	3 9	53¾	1,680	18	1,440
24	·035	792	29·04	4 1	3 10	52½	1,640	16½	1,320
25	·145	3,280	29·27	4 0	3 8	61	1,900	37½	3,000
26	·130	2.940	29·59	3 7	3 7	62½	1,960	45	3,600
27	·112	2,534	29·70	3 7	3 3	57½	1,800	21	1,680
28	..	..	29·79	3 9	3 5	56¼	1,770	11	880
29	..	..	29·70	3 10½	3 6½	51¼	1,595	10½	840
30	..	..	29·73	4 0	3 9	45	1,395	9	720
31	·100	2,262	29·58	4 0½	3 8	47½	1,480	9¾	780
Total	2·333	52,775		Total quantity of Water per Acre discharged			43,855	..	39,090
				Remainder unaccounted for			8,920	..	13,685
				Total Rainfall ..			52,775	..	52,775

OF THE MONTH OF JANUARY, 1857.

10	11	12		13		14		15	16	17	18	19	20	21	22
PARALLEL DRAINAGE. Fields 13 and part 14.—24 Acres. Soil, Gault Clay, with Lime infiltrated. Patches and veins of Sand found giving vent to Underwater which has run through the Summer of 1856.		CLOSE PARALLEL DRAINAGE. Fields Nos. 31, 32, and 33.—Nos. 31 and 32 only drained. 29 Acres. No. 33 undrained. Soil, Gault Clay, with Lime infiltrated. Considered very stiff and impenetrable. Drains, 25 feet apart, and 4 feet deep.								TEMPERATURE. At half-past Seven, A.M.					
										Undrained Land.			Drained Land.		
Quantity of Water from Outlet No. 13, which discharges the Drain Water from Nos. 13 and part 14. Size of Pipe, 5 inches. Has run throughout the year.		Observations on Test Holes, being the depth of free soil from surface of Land to surface of Water in the Holes, which are sunk midway between the Drains. (See also Temperature.) Test Holes 5 feet deep.						Quantity of Water from Outlet No. 15, which discharges the Drain Water from Nos. 31 and 32. Size of Pipe, 7 inches. Commenced running Nov. 27.		Of Air 9 in. above surface. No. 33.	Of Soil 18 in. below ground. No. 33.	Of Soil 42 in. below ground. No. 33.	Of Air 9 in. above surface. No. 31.	Of Soil 18 in. below ground. No. 31.	Of Soil 42 in. below ground. No. 31.
		Drained Land.													
Per Minute. In Gallons	Per Acre. In Gallons (per diem).	Higher Side. 25 ft. apart and 4 ft. deep. No. 31.		Lower Side. 25 ft. apart and 4 ft. deep. No. 31.		Undrained Land No. 33.		Per Minute. In Gallons.	Per Acre. In Gallons (per diem).						
4¼	250	4	6	4	6	1	2	2	100	No observations made prior to the 6th of this month.					
5	300	4	6	4	6	1	2	3⅜	170						
9¼	550	4	5	4	5	1	2	8	400						
33	1,900	4	4	4	4	1	2	18	900						
40½	2,430	4	3	4	3	1	1½	21	1,050						
19½	1,170	4	3	4	3½	1	3	12	600	31	..	No observations recorded.	31	..	No observations recorded.
18½	1,130	4	3	4	3½	1	2½	4½	225	32	34		33	34	
9	540	4	3	4	3	1	3	3	150	34	34		36	35	
8	480	4	3	4	3½	1	3	2½	125	37	35		38	36	
101½	6,060	4	0	4	0	0	5	103	5,150	44	36		44	37	
75	4,500	4	0	4	0	0	5	80	4,000	37	37		43	38	
46½	2,790	3	11	3	11	0	4	40	1,990	37	37		32	38	
35	2,085	4	0	4	0	0	5	25	1,250	32	37		31	37	
18	1,080	4	0	4	0	0	6	12	600	28	36		29	37	
11¼	660	4	0	4	0	0	9	7½	375	32	35		33	35	
14¼	840	4	1	4	1	1	0	8¼	410	27	34		31	35	
13½	810	4	1½	4	2	1	0	7½	375	29	31		33	34	
14¼	850	4	1	4	2	1	0	7½	375	43	30		44	35	
15¾	945	4	1	4	2	1	0	7½	375	41	36		42	36	
16¾	1,005	4	0	4	0	1	0½	8¼	410	38	32		39	37	
24	1,440	3	10½	3	10	1	0	13½	680	32	31		32	36	
24¾	1,485	3	10	3	10	0	10	19¾	985	29	32		30	37	
24	1,440	3	9	3	9	0	9	19¾	985	32	31		34	35	
22¼	1,310	3	9½	3	9	0	10	18	900	35	33		36	37	
56¼	3,400	3	8	3	9	0	10	54	2,700	34	32		35	36	
57½	3,450	3	5	3	9	0	10	55	2,750	31	32		32	34	
41½	2,460	3	2½	3	2½	1	0	35	1,750	28	33		29	35	
20¼	1,200	3	3	3	3	1	0	15	750	17	33		18	35	
16⅔	995	3	3½	3	3½	1	0	11¼	560	16	32		17	34	
13¼	795	3	4	3	4	1	0	6¾	340	21	31		22	33	
15	900	3	3	3	3	0	11	7½	375	30	33		31	34	
..	49.250	..		..		..		..	31,805	..	..		..	..	
..	3,525	..		..		..		..	20,970	..	..		..	..	
..	52,775	..		..		..		..	52,775	..	..		..	..	

Hinxworth Drainage.—Record

	1	2	3	4	5	6	7	8	9
	Rainfall.		Barometer.	Occasional Drainage.				Part Occasional and part Wide Parallel Drainage.	
				Fields Nos. 18, 19, 20.—46 Acres. Soil, lower Chalk mixed with Clay, Gravel, and Sand. Green Sand is found mixed with Gault Clay. Also Coprolites. Very wet before Draining.				Field No. 22. 18 Acr. Soil, same as last in part of field, remainder Gault and Gravel mixed.	
				Observations on Test Holes, being the depth of free soil from surface of Land to surface of Water in the Holes, which are sunk midway between the occasional Drains. Test Holes 6 feet deep.		Quantity of Water from Outlet No. 7, which discharges the Drain Water from 18, 19, and 20. Size of Pipe, 8 inches. Commenced running October 1.		Quantity of Water from Outlet No. 9, which discharges the Drain Water from No. 22. Size of Pipe, 5 inches. Commenced running October 12.	
Day of the Month.	Per Diem. Inches dec.	Per Acre. (Per Diem.) In Gallons.	Height at the time of recording the Discharge from the Outlets, 8 o'clock, A.M. *Note.*—It should be observed that the height recorded is simply the height of the mercury at a certain time of day.	Higher Side. Distance from Drain to Drain 59 yds. Depth of Drains 4 ft. 11 in.	Lower Side. Distance from Drain to Drain 57 yds. Depth of Drains 4 ft. 4 in.	Per Minute. In Gallons.	Per Acre. In Gallons (per diem).	Per Minute. In Gallons.	Per Acre. In Gallons (per diem).
1	..	..	29·79	4 1	3 8	40	1,245	7	560
2	..	..	29·59	4 2	3 8½	33¾	1,055	6¾	540
3	..	..	29·60	4 3½	3 9	32½	1,015	6	480
4	..	..	30·07	4 5	3 10	32½	1,015	4½	360
5	..	..	30·08	4 6	3 11½	35	1,095	6	480
6	·100	2,262	29·77	4 5	3 11	38¾	1,210	12¾	1,020
7	·025	565½	29·67	4 4	3 10	50	1,560	16½	1,320
8	..	..	29·59	4 4	4 0	45	1,395	12	960
9	..	..	29·58	4 4	4 1	41½	1,285	9	720
10	·022	497½	29·57	4 5	4 2	40	1,245	9	720
11	·020	452½	29·69	4 6	4 3	37½	1,175	8½	680
12	·010	226¼	30·20	4 7	4 4	36½	1,150	6¾	540
13	..	..	30·20	4 7½	4 4	37½	1,175	6¾	540
14	..	..	30·20	4 8	4 4	35	1,090	6¼	540
15	..	..	30·16	4 8	4 4	32	1,000	6	480
16	..	..	30·05	4 9	4 4	30	935	6	480
17	..	..	30·00	4 9½	4 4	27½	860	4½	360
18	..	..	29·90	4 10	4 4	27½	860	4½	360
19	..	..	30·09	4 10½	4 4	26¼	820	4½	360
20	·015	339¼	30·14	4 10½	4 4	25	780	4½	360
21	..	..	30·18	4 11	4 4	23¾	745	4	320
22	..	..	30·19	4 11	4 4	22	690	4	320
23	..	..	30·19	4 11	4 4	21	660	4	320
24	..	..	30·20	4 11	4 4	21	660	3¾	300
25	..	..	30·10	4 11	4 4	21	660	3¾	300
26	..	..	30·38	4 11	4 4	21	660	3¾	300
27	..	..	30·37	4 11	4 4	21	660	3¾	300
28	..	..	30·39	4 11	4 4	21	660	3¾	300
Total	·192	4,343		Total quantity of Water per Acre discharged ..			27,360	..	14,320
				Rainfall			4,343	..	4,343
				Excess discharged from soil			23,017	..	9,977

OF THE MONTH OF FEBRUARY, 1857.

10	11	12	13	14	15	16	17	18	19	20	21	22
PARALLEL DRAINAGE.		CLOSE PARALLEL DRAINAGE.					TEMPERATURE.					
Fields 13 and part 14.—24 Acres. Soil, Gault Clay, with Lime infiltrated. Patches and veins of Sand found giving vent to Under-water which has run through the Summer of 1856.		Fields Nos. 31, 32, and 33.—Nos. 31 and 32 only drained. 29 Acres. No. 33 undrained. Soil, Gault Clay, with Lime infiltrated. Considered very stiff and impenetrable. Drains, 25 feet apart, and 4 feet deep.					At half-past Seven, A.M.					
							Undrained Land.			Drained Land.		
Quantity of Water from Outlet No. 13, which discharges the Drain Water from Nos. 13 and part 14. Size of Pipe, 5 inches. Has run throughout the year.		Observations on Test Holes, being the depth of free soil from surface of Land to surface of Water in the Holes, which are sunk midway between the Drains. (See also Temperature.) Test Holes 5 feet deep.			Quantity of Water from Outlet No. 15, which discharges the Drain Water from Nos. 31 and 32. Size of Pipe, 7 inches. Commenced running Nov. 27.		Of Air 9 in. above surface. No. 33.	Of Soil 18 in. below ground. No. 33.	Of Soil 42 in. below ground. No. 33.	Of Air 9 in. above surface. No. 31.	Of Soil 18 in. below ground. No. 31.	Of Soil 42 in. below ground. No. 31.
		Drained Land.		Un-drained Land No. 33.								
Per Minute. In Gallons.	Per Acre. In Gallons (per diem).	Higher Side. 25 ft. apart and 4 ft. deep. No. 31.	Lower Side. 25 ft. apart and 4 ft. deep. No. 31.		Per Minute. In Gallons.	Per Acre. In Gallons (per diem).						
12	720	..	..	1 0	7	350	27	32	No observations recorded prior to the 21st of this month.	28	33	39
8¼	495	3 1½	3 3½	1 0	6	300	25	32		26	33	39
6¾	405	3 2	3 4	1 1	5¼	260	21	32		22	33	38
5¼	315	3 3	3 5	1 2	3¾	185	24	31		25	32	38
6¾	405	3 4	3 6	1 2	5¼	265	26	32		27	33	38
9½	570	3 2	3 4	1 2	9	450	27	32		28	33	38
31½	1,890	2 10	3 0	1 0	25	1,250	40	31		41	33	38
18	1,080	2 10	2 11	1 0	17	850	38	32		39	34	38
10½	630	2 10	2 11	1 0	12	600	44	32		45	33	38
9¾	585	2 10	2 11	1 1	9	450	35	33		36	34	37
10½	630	3 0	2 11	1 2	7½	375	35	34		36	35	37
9¾	585	3 1	3 0	1 2	7½	375	31	35		32	36	38
9¾	585	3 2	3 1	1 2	7½	375	32	35		33	36	38
9	540	3 3	3 2	1 2½	7½	375	40	34		40	35	38
8¾	525	3 3	3 2	1 3	6½	325	32	34		33	35	38
8¾	525	3 4	3 3	1 3	6	300	25	35		25	36	39
7½	450	3 4½	3 4	1 3	5¼	260	42	35		41	35	40
6¼	375	3 5	3 5	1 3½	4½	225	40	35		40	36	40
6¼	375	3 5½	3 6	1 3½	3¾	185	42	35		41	37	40
5	300	3 6	3 6½	1 3½	3¾	185	40	36		39	38	40
5	300	3 6½	3 7	1 4	3	150	42	37		40	39	41
4	240	3 7	3 8	1 5	3	150	42	37	39	42	39	41
3¾	225	3 7	3 8	1 5½	3	150	34	37	39	34	39	41
3	180	3 7½	3 8	1 6	3	150	40	37	39	40	39	41
3	180	3 8	3 8½	1 6	3	150	30	37	39	31	39	41
3	180	3 8	3 9½	1 6	3	150	23	37	39	23	39	41
3	180	3 8	3 10½	1 6	2¼	110	36	37	39	36	39	41
3	180	3 8½	3 11½	1 6	2¼	110	43	37	39	43	39	41
..	13,650	..	..	..	..	9,060	..	..	..	..	..	..
..	4,343	..	..	..	..	4,343	..	..	..	..	..	..
..	9,307	..	..	..	..	4,717	..	..	..	..	..	..

HINXWORTH DRAINAGE.—RECORD

	1	2	3	4	5	6	7	8	9
	RAINFALL.		BAROMETER.	OCCASIONAL DRAINAGE.				PART OCCASIONAL AND PART WIDE PARALLEL DRAINAGE.	
				Field No. 40.—16 Acres. Soil, lower Chalk mixed with Clay, Gravel, and Sand. Very wet before Draining. (The fields are changed because Coprolites were raised in No. 19 this month, and interfered with the discharge.)				18 Acres. — Soil, same as last in part of field, remainder Gault and Gravel mixed.	
				Observations on Test Holes, being the depth of free soil from surface of Land to surface of Water in the Holes, which are sunk midway between the occasional Drains. Test Holes 8 feet deep.		Quantity of Water from Outlet No. 8, which discharges the Drain Water from Field No. 40.		Quantity of Water from Outlet No. 9, which discharges the Drain Water from No. 22. Size of Pipe, 5 inches. Commenced running October 12.	
Day of the Month.	Per Diem. Inches dec.	Per Acre. (Per Diem.) In Gallons.	Height at the time of recording the Discharge from the Outlets, 8 o'clock, A.M. *Note.*—It should be observed that the height recorded is simply the height of the mercury at a certain time of day.	Higher Side. Distance from Drain to Drain 75 yds. Depth of Drains 7 ft. 6 in.	Lower Side. Distance from Drain to Drain 33 yds. Depth of Drains 6 ft.	Per Minute. In Gallons.	Per Acre. In Gallons (per diem).	Per Minute. In Gallons.	Per Acre. In Gallons (per diem).
1	..	..	30·49	4 2	5 6½	4½	405	3¾	300
2	..	..	30·48	4 2½	5 6½	4½	405	3¾	300
3	..	.	30·39	4 2½	5 6½	4½	405	3⅛	250
4	..	..	30·08	4 3	5 6½	4½	405	3	240
5	..	..	30·28	4 3½	5 6½	4½	405	2⅝	210
6	..	..	30·00	4 4	5 6½	5¼	472½	3¾	300
7	..	..	29·85	4 4½	5 6½	5¼	472½	3¾	300
8	..	..	29·49	4 5	5 6½	5	450	3¾	300
9	·030	675	29·66	4 5	5 7	4½	405	2⅝	210
10	·050	1,130	29·90	4 6	5 7	4½	405	3	240
11	·065	1,470	29·80	4 7	5 7	5¼	472½	3½	280
12	..	..	29·89	4 8	5 7	5¼	472½	4½	360
13	..	..	29·79	4 9	5 7	5¼	472½	4½	360
14	·060	1,360	29·00	4 9½	5 7	5¼	472½	5¼	420
15	·033	746	29·25	4 9½	5 7	5	450	4½	360
16	..	..	29·79	4 10	5 7	3	270	3¾	300
17	..	..	29·80	4 11	5 7	2¼	200	3¾	300
18	..	..	29·69	5 0	5 7	1½	135	4¼	180
19	·040	905	29·79	5 1	5 7	¾	67½	3¾	300
20	·100	2,262	29·80	5 1½	5 7	¾	67½	2¼	180
21	..	..	30·00	5 2	5 7	¾	67½	2¼	180
22	..	..	29·80	5 2	5 7	¾	67½	2¼	180
23	·122	2,760	29·60	5 2½	5 7	1½	135	2¼	180
24	·010	227	29·59	5 3	5 7	1½	135	2¼	180
25	·015	339	29·40	5 3	5 7	1½	135	2¼	180
26	·005	113	29·59	5 3	5 7	¾	67½	2¼	180
27	..	..	29·88	5 3	5 7	¾	67½	2¼	180
28	..	..	30·00	5 3½	5 7	¾	70	2½	200
29	·030	678	29·78	5 3	5 6	1	90	2½	200
30	·180	4,072	29·28	5 3	5 6	1½	135	3	240
31	·080	1,810	29·18	5 3	5 6	1½	135	3	240
Total	·820	18,547		Total quantity of Water per Acre discharged			8,415	..	7,830
				Remainder unaccounted for			10,132	..	10,717
				Total Rainfall ..			18,547	..	18,547

OF THE MONTH OF MARCH, 1857.

10	11	12	13	14	15	16	17	18	19	20	21	22
PARALLEL DRAINAGE.		CLOSE PARALLEL DRAINAGE.					TEMPERATURE. At half-past Seven, A.M.					
Fields 13 and part 14.—24 Acres. Soil, Gault Clay, with Lime infiltrated. Patches and veins of Sand found giving vent to Under-water which has run through the Summer of 1856.		Fields Nos. 31, 32, and 33.—Nos. 31 and 32 only drained. 29 Acres. No. 33 undrained. Soil, Gault Clay, with Lime infiltrated. Considered very stiff and impenetrable. Drains, 25 feet apart, and 4 feet deep.										
Quantity of Water from Outlet No. 13, which discharges the Drain Water from Nos. 13 and part 14. Size of Pipe, 5 inches. Has run throughout the year.		Observations on Test Holes, being the depth of free soil from surface of Land to surface of Water in the Holes, which are sunk midway between the Drains. (See also Temperature.) Holes 5 feet deep.			Quantity of Water from Outlet No. 15, which discharges the Drain Water from Nos. 31 and 32. Size of Pipe, 7 inches. Commenced running Nov. 27.		Undrained Land.			Drained Land.		
		Drained Land.										
Per Minute In Gallons.	Per Acre. In Gallons (per diem)	Higher Side. 25 ft. apart and 4 ft. deep. No. 31.	Lower Side. 25 ft. apart and 4 ft. deep. No. 31.	Un-drained Land No. 33.	Per Minute. In Gallons.	Per Acre. In Gallons (per diem).	Of Air 9 in. above surface. No. 33.	Of Soil 18 in. below ground. No. 33.	Of Soil 42 in. below ground. No 33.	Of Air 9 in. above surface. No. 31.	Of Soil 18 in. below ground. No. 31.	Of Soil 42 in. below ground. No. 31.
3	180	3 9	3 11	1 6	2¼	110	35	37	39	36	40	41
3	180	3 9	3 11	1 6	2¼	110	43	37	39	44	40	41
3	180	3 9	4 0	1 6	2¼	110	43	38	40	44	41	43
3	180	3 9½	4 0	1 6	2¼	110	44	38	40	43	41	42
3	180	3 9½	4 0	1 6	2¼	110	24	38	40	25	41	42
4½	270	3 9½	4 0	1 6	3	150	45	38	40	45	41	42
4½	270	3 9½	4 0	1 6	3	150	34	38	40	34	41	42
4½	270	3 10	4 0	1 6	3	150	47	38	40	46	41	42
4½	270	3 10	4 0	1 6	3	150	38	37	40	39	40	42
5¼	315	3 10	4 0	1 6	3¾	185	27	36	39	28	39	41
6	360	3 10	4 0	1 6	4½	225	31	36	39	32	38	41
6	360	3 10	4 0	1 6	4½	225	32	36	39	32	38	41
5¼	315	3 10	4 0	1 6	3¾	185	31	36	39	31	38	41
5¼	315	3 10	4 0	1 6	3¾	185	42	36	40	42	39	41
4	240	3 10	4 0	1 6	3	150	43	37	40	44	40	41
3	180	3 10	4 0	1 6	2¼	112	37	38	40	37	40	41
2¼	135	3 10	4 0	1 6	1½	75	42	38	40	42	40	41
3	180	3 10	4 0	1 6½	1½	75	46	38	40	46	40	41
1½	90	3 11½	4 0	1 7	¾	37	49	40	41	48	42	42
1½	90	3 11½	4 0	1 7½	¾	38	47	41	41	47	43	42
1½	90	4 0	4 0	1 7½	¾	38	36	41	41	37	43	42
1½	90	4 0	4 0	1 7½	¾	38	34	40	41	35	42	42
1½	90	4 0	4 0	1 7	¾	38	33	39	41	34	41	42
2¼	135	4 0	4 0	1 7	1½	75	38	38	41	38	40	42
2¼	135	4 0	4 0	1 7	1½	95	43	38	41	43	40	42
1½	90	4 0	4 0	1 7	¾	38	38	38	41	38	40	42
1½	90	4 0	4 0	1 7	¾	38	41	39	41	42	41	42
1½	90	4 0	4 0	1 7	¾	38	42	40	41	43	42	42
2	120	4 0	4 0	1 6	1	50	41	40	41	41	42	42
3	180	4 0	4 0	1 5	2¼	110	42	40	42	42	42	43
3	180	3 11½	3 11½	1 4	2¼	110	42	41	42	43	43	43
..	5,850	..	..	..	..	3 310	..	..	..	..	..	..
..	12,697	..	..	..	..	15,237	..	..	..	..	..	..
..	18,547	..	..	..	..	18,547	..	..	..	..	..	..

HINXWORTH DRAINAGE.—RECORD

	1	2	3	4	5	6	7	8	9
	RAINFALL.		BAROMETER.	OCCASIONAL DRAINAGE.				PART OCCASIONAL AND PART WIDE PARALLEL DRAINAGE.	
				Field No. 40.—16 Acres. Soil, lower Chalk mixed with Clay, Gravel, and Sand. Very wet before Draining.				18 Acres. — Soil, same as last in part of field, remainder Gault and Gravel mixed.	
				Observations on Test Holes, being the depth of free soil from surface of Land to surface of Water in the Holes, which are sunk midway between the occasional Drains. Test Holes 8 feet deep.		Quantity of Water from Outlet No. 8, which discharges the Drain Water from Field No. 40.		Quantity of Water from Outlet No. 9, which discharges the Drain Water from No. 22. Size of Pipe, 5 inches. Commenced running October 12.	
Day of the Month.	Per Diem. Inches dec.	Per Acre. (Per Diem.) In Gallons.	Height at the time of recording the Discharge from the Outlets, 8 o'clock, A.M. *Note.*—It should be observed that the height recorded is simply the height of the mercury at a certain time of day.	Higher Side. Distance from Drain to Drain 75 yds. Depth of Drains 7 ft. 6 in.	Lower Side. Distance from Drain to Drain 33 yds. Depth of Drains 6 ft.	Per Minute. In Gallons.	Per Acre. In Gallons (per diem).	Per Minute. In Gallons.	Per Acre. In Gallons (per diem).
1	·050	1,131	29·37	5 3	5 6	¾	67	2¼	180
2	..	..	29·15	5 3	5 6	¾	67	2¼	180
3	·015	339	29·48	5 3½	5 6	¾	68	2¼	180
4	·060	1,357	29·67	5 4	5 6	¾	68	2¼	180
5	·460	10,406	29·69	5 6	5 6	3	270	9	720
6	·035	792	29·58	5 8	5 6	3	270	9	720
7	..	..	29·80	5 8	5 6	3	270	6	480
8	..	..	29·89	5 8	5 6	3	270	6	480
9	·005	113	29·58	5 8	5 6	3	270	5¼	420
10	·080	1,810	29·48	5 8	5 6	2¼	200	4½	360
11	·030	678	29·40	5 8	5 6	2¼	200	3¾	300
12	·035	772	29·35	5 8	5 6	3	270	3¾	300
13	·300	6,786	29·87	5 8	5 6	3¾	338	5¼	420
14	·150	3,394	29·20	5 8	5 5½	3	270	8¼	660
15	·005	115	29·46	5 8	5 5½	3	270	6	480
16	..	..	29·65	5 8	5 5½	3	270	5¼	420
17	·005	110	29·83	5 8½	5 6	3	270	4½	360
18	..	..	29·83	5 8½	5 6	3	270	4½	360
19	..	..	29·78	5 8½	5 6½	2½	215	4½	360
20	..	..	30·10	5 8½	5 6½	2¼	200	4½	360
21	..	..	30·18	5 9	5 7	2¼	200	4½	360
22	..	..	30·00	5 8½	5 6	3	270	5¼	420
23	·205	4,650	29·90	5 8	5 5	3	270	5¼	420
24	..	..	30·76	5 9	5 6	3	270	3¾	300
25	..	..	29·69	5 10	5 6	3	270	3¾	300
26	·005	113	29·80	5 10	5 6	2½	225	3	240
27	..	..	30·00	5 10	5 6	2¼	200	3	240
28	..	..	30·03	5 10	5 6	2¼	200	3	240
29	..	..	30·00	5 10	5 6	2¼	200	3	240
30	..	..	30·00	5 10	5 6	2¼	200	3	240
Total	1·440	32,566		Total quantity of Water per Acre discharged ..			6,698	..	10,920
				Remainder unaccounted for			25,868	..	21,646
				Total Rainfall..			32,566	..	32,566

OF THE MONTH OF APRIL, 1857.

10	11	12	13	14	15	16	17	18	19	20	21	22
PARALLEL DRAINAGE.		CLOSE PARALLEL DRAINAGE.					TEMPERATURE.					
Fields 13 and part 14.—24 Acres. Soil, Gault Clay, with Lime infiltrated. Patches and veins of Sand found giving vent to Underwater which has run through the Summer of 1856.		Fields Nos. 31, 32, and 33.—Nos. 31 and 32 only drained. 29 Acres. No. 33 undrained. Soil, Gault Clay, with Lime infiltrated. Considered very stiff and impenetrable. Drains, 25 feet apart, and 4 feet deep.					At half-past Seven, A.M.					
							Undrained Land.			Drained Land.		
Quantity of Water from Outlet No. 13, which discharges the Drain Water from Nos. 13 and part 14. Size of Pipe, 5 inches. Has run throughout the year.		Observations on Test Holes, being the depth of free soil from surface of Land to surface of Water in the Holes, which are sunk midway between the Drains. (See also Temperature.) Holes 5 feet deep.			Quantity of Water from Outlet No. 15, which discharges the Drain Water from Nos. 31 and 32. Size of Pipe, 7 inches. Commenced running Nov. 27.							
		Drained Land.										
Per Minute In Gallons.	Per Acre. In Gallons (per diem).	Higher Side. 25 ft. apart and 4 ft. deep. No. 31.	Lower Side. 25 ft. apart and 4 ft. deep. No. 31.	Un-drained Land No. 33.	Per Minute. In Gallons.	Per Acre. In Gallons (per diem).	Of Air 9 in. above surface. No. 33.	Of Soil 18 in. below ground. No. 33.	Of Soil 42 in. below ground. No. 33.	Of Air 9 in. above surface. No. 31.	Of Soil 18 in. below ground. No. 31.	Of Soil 42 in. below ground. No. 31.
1½	90	3 11½	3 11½	1 3	2¼	110	45	41	42	45	43	43
1½	90	3 11½	3 11½	1 3	1½	75	46	42	42	49	44	43
1½	90	3 11½	3 11½	1 3	1½	75	48	42	42	47	44	43
1½	90	4 0	4 0	1 3½	¾	37	47	43	42	48	45	43
13½	810	4 0	3 11½	1 3	8¼	410	44	44	43	45	46	44
13½	810	4 0	3 11	1 2	8¼	415	42	45	43	46	47	44
12	720	4 0	3 11	1 2	7½	375	45	46	43	46	48	44
10½	630	4 0	3 11	1 3	6	300	46	46	44	47	48	45
7½	450	4 0	3 11	1 4	5¼	265	44	46	44	45	48	45
6¾	405	4 0	3 11	1 5	4½	225	45	47	44	44	49	45
6	360	4 0	4 0	1 5	3¾	185	44	47	44	45	49	45
6	360	4 0	4 0	1 5	4¼	200	45	46	44	46	48	45
8¼	495	4 0	4 0	1 4	5¼	265	42	45	44	42	47	45
15	900	4 0	4 0	1 4	11¼	560	37	44	44	37	45	45
9	540	4 0	4 0	1 4	5¼	265	41	43	44	41	44	45
7½	450	4 0	4 0	1 4	4½	225	43	43	44	43	44	45
6	360	4 0	4 0	1 4	4½	225	44	42	44	44	43	45
5¼	315	4 0	4 0	1 4	4½	225	46	43	44	46	44	45
4½	270	4 0	4 0	1 4	4½	225	43	44	44	43	45	45
4½	270	4 0	4 0	1 4	4½	225	42	44	44	42	46	45
3¾	225	4 0	4 0	1 4	3¾	185	42	45	44	42	47	45
4½	270	4 0	4 0	1 4	3¾	185	40	46	45	40	48	46
4½	270	3 11½	4 0	1 3	3¾	185	38	46	45	39	48	46
4½	270	3 11	4 0	1 3	3	148	37	46	45	38	48	46
3¾	225	3 11½	4 0	1 3	3	148	43	45	45	43	47	46
3	180	4 0	4 0	1 3	2¼	110	39	44	45	39	46	46
3	180	4 0	4 0	1 3	2¼	110	37	43	45	37	45	46
2¼	135	4 0	4 0	1 3	1½	75	38	42	44	38	44	45
2¼	135	4 0	4 0	1 3	1½	75	41	42	44	41	44	45
2¼	135	4 0	4 0	1 3	1½	75	40	42	44	40	44	45
..	10,530	..	..	..	..	6,183	..	..	..	..	..	..
..	22,036	..	..	..	..	26,383	..	..	..	..	..	..
..	32,566	..	..	..	..	32,566	..	..	..	..	..	..

HINXWORTH DRAINAGE.—RECORD

	1	2	3	4	5	6	7	8	9
	RAINFALL.		BAROMETER.	OCCASIONAL DRAINAGE.				PART OCCASIONAL AND PART WIDE PARALLEL DRAINAGE.	
				Field No. 40.—16 Acres. Soil, lower Chalk mixed with Clay, Gravel, and Sand. Very wet before Draining.				18 Acres. — Soil, same as last in part of field, remainder Gault and Gravel mixed.	
			Height at the time of recording the Discharge from the Outlets, 8 o'clock, A.M. *Note.*—It should be observed that the height recorded is simply the height of the mercury at a certain time of day.	Observations on Test Holes, being the depth of free soil from surface of Land to surface of Water in the Holes, which are sunk midway between the occasional Drains. Test Holes 8 feet deep.		Quantity of Water from Outlet No. 8, which discharges the Drain Water from Field No. 40.		Quantity of Water from Outlet No. 9, which discharges the Drain Water from No. 22. Size of Pipe, 5 inches. Commenced running October 12.	
Day of the Month.	Per Diem. Inches dec.	Per Acre. (Per Diem.) In Gallons.		Higher Side. Distance from Drain to Drain 75 yds. Depth of Drains 7 ft. 6 in.	Lower Side. Distance from Drain to Drain 33 yds. Depth of Drains 6 ft.	Per Minute. In Gallons.	Per Acre. In Gallons (per diem).	Per Minute. In Gallons.	Per Acre. In Gallons (per diem).
1	·040	905	30·07	5 10½	5 6	1½	135	3	240
2	·005	113	30·06	5 11	5 6	1½	135	3	240
3	..	..	30·17	5 11	5 6	3	270	3	240
4	..	..	30·18	5 11	5 6	3	270	3	240
5	..	..	30·19	5 11	5 6	3	270	3	240
6	·010	226	30·20	5 11	5 6	3	270	3	240
7	..	..	30·19	5 11½	5 6½	2¼	200	2¼	180
8	..	..	30·05	5 11½	5 6½	2¼	200	2¼	180
9	..	..	29·79	6 0	5 6½	2¼	200	2¼	180
10	..	..	29·68	6 1	5 6½	1½	135	2¼	180
11	·150	3,393	29·60	6 1	5 6½	1½	135	2¼	180
12	·050	1,131	29·80	6 1	5 6½	1½	135	3	240
13	·010	226	30·00	6 1½	5 6	1½	135	3	240
14	..	..	30·00	6 2	5 7	1½	135	2¼	180
15	..	..	30·01	6 2½	5 7	1½	135	2¼	180
16	·055	1,245	30·10	6 3	5 7	1½	135	2¼	180
17	..	..	30·09	6 3½	5 7½	1½	135	1½	120
18	..	..	30·00	6 3½	5 7½	1½	135	1½	120
19	..	..	29·95	6 4	5 8	¾	67	1½	120
20	..	..	29·80	6 4½	5 8½	¼	23	1½	120
21	..	..	29·60	6 5	5 9	¼	22	1½	120
22	·040	905	29·76	6 5	5 9½	Nil	Nil	1½	120
23	·170	3,845	29·60	6 6	5 10	Nil	Nil	2	160
24	·030	678	29·41	6 6	5 11	1½	135	1½	120
25	..	..	29·46	6 6	6 0	1½	135	1½	120
26	·180	4,074	29·48	6 6	6 3	1½	135	1½	120
27	..	..	29·64	6 6½	6 3	1½	135	1½	120
28	..	..	29·70	6 6½	6 4	1	90	1	80
29	..	..	29·80	6 7½	6 5	1	90	1	80
30	·010	226	29·89	6 7½	6 6	1	90	1	80
31	..	..	29·95	6 8	6 6½	1	90	1	80
Total	·750	16,967		Total quantity of Water per Acre discharged ..			4,177	..	5,040
				Remainder unaccounted for			12,790	..	11,927
				Total Rainfall ..			16,967	..	16,967

UNIVERSITY OF CALIFORNIA

OF THE MONTH OF MAY, 1857.

10	11	12	13	14	15	16	17	18	19	20	21	22
PARALLEL DRAINAGE. Fields 13 and part 14.—24 Acres. Soil, Gault Clay, with Lime infiltrated. Patches and veins of Sand found giving vent to Under-water which has run through the Summer of 1856.		CLOSE PARALLEL DRAINAGE. Fields Nos. 31, 32, and 33.—Nos. 31 and 32 only drained. 29 Acres. No. 33 undrained. Soil, Gault Clay, with Lime infiltrated. Considered very stiff and impenetrable. Drains, 25 feet apart and 4 feet deep.					TEMPERATURE. At half-past Seven, A.M.					
							Undrained Land.			Drained Land.		
Quantity of Water from Outlet No. 13, which discharges the Drain Water from Nos. 13 and part 14. Size of Pipe, 5 inches. Has run throughout the year.		Observations on Test Holes, being the depth of free soil from surface of Land to surface of Water in the Holes, which are sunk midway between the Drains. (See also Temperature.) Test Holes 5 feet deep.			Quantity of Water from Outlet No. 15, which discharges the Drain Water from Nos. 31 and 32. Size of Pipe, 7 inches. Commenced running Nov. 27.							
		Drained Land.										
Per Minute. In Gallons.	Per Acre. In Gallons (per diem).	Higher Side. 25 ft. apart and 4 ft. deep. No. 31.	Lower Side. 25 ft. apart and 4 ft. deep. No. 31.	Undrained Land No. 33.	Per Minute. In Gallons.	Per Acre. In Gallons (per diem).	Of Air 9 in. above surface. No. 33.	Of Soil 18 in. below ground. No. 33.	Of Soil 42 in. below ground. No. 33.	Of Air 9 in. above surface. No. 31.	Of Soil 18 in. below ground. No. 31.	Of Soil 42 in. below ground. No. 31.
2¼	135	4 0	4 0	1 3½	1½	74	42	42	44	42	44	45
2¼	135	4 0	4 0	1 4	1½	74	44	43	44	44	45½	45
2¼	135	4 0	4 0	1 4	1½	74	43	43	45	43	45½	46
2¼	135	4 0	4 0	1 4	1½	74	44	43	45	44	45½	46
2¼	135	4 0	4 0	1 4	1½	74	41	44	45	41	46	46
1½	90	4 0	4 0	1 4½	1½	75	38	43	45	39	45	46
1½	90	4 0	4 0	1 4½	1½	75	38	43	45	38	45	46
1½	90	4 0	4 0	1 5	¾	37	40	43	45	40	45½	46
1½	90	4 0	4 0	1 5	¾	37	45	44	45	45	46	46
2	120	4 0	4 0	1 5	1	49	44	44	45	44	46	46
2¼	135	4 0	4 0	1 5	1½	75	47	45	45	48	47	46
2¼	135	4 0	4 0	1 5	1½	75	49	46	45	50	48	46
3	180	4 0	4 0	1 5	1½	75	52	48	45	53	50	46
2¼	135	4 0	4 0	1 5½	1½	75	53	49	46	54	51	47
1½	90	4 0	4 0	1 6	2¼	110	56	51	47	56	53	48
1½	90	4 0	4 0	1 6	2¼	110	58	52	48	58	55	49
¾	45	4 0	4 0	1 6	2¼	110	58	52	48	58	55	49
1	60	4 0	4 0	1 6	2¼	110	60	51	48	60	54	49
1	60	4 0	4 0	1 6	2¼	110	63	50	48	63	53	49
¾	45	4 0	4 0	1 6	2¼	110	63	51	48	64	54	50
¾	45	4 0	4 0	1 6½	2¼	110	65	54	49	65	56	51
¾	45	4 0	4 0	1 6½	2¼	110	66	54	50	66	56	51
1	60	4 0	4 0	1 6	3	148	64	54	50	63	56	51
1	60	4 0	4 0	1 6	3½	173	61	54	50	62	56	51
1	60	4 0	4 0	1 6	3¾	185	60	54	50	61	56	51
1½	90	4 0	4 0	1 6	4	198	61	54	49	60	55	51
1½	90	4 0	4 0	1 6	4	199	62	53	49	62	55	52
1	60	4 0	4 0	1 6½	3¾	185	62	53	50	61	56	52
¾	45	4 0	4 0	1 6½	3¾	185	61	53	50	60	56	52
¾	45	4 0	4 0	1 7	3	149	62	53	49	62	56	52
¾	45	4 0	4 0	1 7	3½	173	..	..	..	..	..	..
..	2,775	..	..	..	..	3,418	..	..	..	..	..	..
..	14,192	..	..	..	..	13,549	..	..	..	..	..	..
..	16,967	..	..	..	..	16,967	..	..	..	..	..	..

SUMMARY OF THE FOREGOING RECORDS.

MONTHS.	RAINFALL.		QUANTITIES DISCHARGED FROM OUTLETS.				MONTHS.
	Inches.	Per Acre. In Gallons.	From Outlet No. 7, from Oct. 1 to Feb. 28, and from Outlet No. 8, from March 1 to May 31, as per Col. 7. Per Acre in Gallons.	From Outlet No. 9, as per Col. 9. Per Acre in Gallons.	From Outlet No. 13, as per Col. 11. Per Acre in Gallons.	From Outlet No. 15, as per Col. 16. Per Acre in Gallons.	
October	1·645	37,215	12,910	178	9,075	Nil.	October.
November	1·630	36,872	27,000	2,077	6,015	330	November.
December	1·235	27,935	30,135	11,895	16,095	5,825	December.
January	2·333	52,775	43,855	39,090	49,250	31,805	January.
February	·192	4,343	27,360	14,320	13,650	9,060	February.
March	·820	18,547	From Outlet No. 8, at a higher level 8,415	7,830	5,850	3,310	March.
April	1·440	32,566	6,698	10,920	10,530	6,183	April.
May	·750	16,967	4,177	5,040	2,775	3,418	May.
Total Rainfall ..	10·045	227,220	160,550	91,350	113,240	59,931	Total discharge per Acre.
Difference between Rainfall and Discharge from the Drains ..			66,670	135,870	113,980	167,289	
			227,220	227,220	227,220	227,220	Total Rainfall.

Mr. G. P. **Bidder**,—President,—said, that the Institution was much indebted to the Author for bringing this subject forward; and he hoped that the various points in the Paper would be freely, candidly, and impartially considered. Engineers would probably not enter with so much interest into the alleged influence of draining on the increase of the crops; but the branch of the subject most interesting to them would most likely be the effect of drainage on the arterial channels and outfalls of the country. The extent to which under-drainage affected the rivers was of particular importance. It was asserted in the Paper that under-drainage did, to some extent, augment the flow of rivers, and thus necessitate a larger water-way under bridges, which were already barely sufficient; in that point of view the subject was one of great importance. He trusted this question would be maturely considered, and that the discussion would throw considerable light on the subject. If the views put forward in the Paper were shown in any instance not to be consistent with recorded facts, he was convinced that no man would be more glad to be set right than the Author.

Mr. **Bailey Denton** remarked, that he had introduced the subject more for the purpose of provoking discussion among Engineers than with the object of advancing his own opinions upon it. Having practised under-drainage somewhat largely, he had experienced some dissatisfaction that there had not been a higher class of talent employed in the direction and inspection of drainage; he thought therefore, that the discussion would show that the question of the effect of under-drainage on the arterial channels of the country was worthy of the consideration of the Institution, and the result would be a more scientific treatment of the whole question in future. In the control of drainage by the Government, owing, perhaps, to the disinclination of the Landed Interest to see men employed of a higher class than those now generally engaged in the lower walks of agriculture, the subject of under-drainage had not received the attention which was due to it. He found, in his communications with the Government inspectors, that they were persons—he would say it with all deference to their special avocations—who were not fully competent to go into so important a question with the various engineering details bearing upon it. They had been, perhaps, selected from a class who were generally considered more suitable for the work than the Civil Engineers of this country, who were usually engaged in constructive works. Now he believed that this was false economy, and that it was much easier for an Engineer to descend to the lower grade of agricultural requirements, than for the agricultural agent to ascend to the higher science of engineering; and it was because he was so thoroughly impressed with the magnitude of the subject, and with the fact of its details and influences not being duly appreciated, that he had ventured to bring it before the Institution.

He particularly desired to express himself clearly with regard to the second result of under-drainage, namely, that of strengthening the perennial springs. He was bound to say, that at an early period of his connection with drainage he entertained a different opinion to that now expressed. He had considered that the result of taking away so much water by under-drainage must be, to leave less in the land to be discharged by means of springs: he had stated that opinion publicly and in print, and he had since found those views quoted, with his name attached as an authority, in American and French papers. He could now only say, he regretted having ever so expressed himself, because, from his more recent experience, he had arrived at a different conclusion. He believed Mr. Charnock's experiments were correct in the main: and, that in the water economy of the country, draining the surcharged free soils would make a considerable difference, but perhaps not to the full extent, 13 inches, stated by Mr. Charnock. The experiments of that gentleman, however, considered in connection with his own observation and practice, had brought him to the conclusion, that the result of under-drainage must be to strengthen the main springs of this country.

The Rev. J. C. Clutterbuck was not prepared to give a decided opinion on the point of the increase of the perennial flow of rivers caused by drainage. He was convinced that this part of the subject required much thought and consideration, as well as careful watching. He hoped that the discussion would lead to more attention being paid to the amount of rainfall in various parts of the country, the records of which were still very imperfect; in fact, information in general on this subject was still greatly in arrear. The Author had done good service by showing the necessity for more attention to that point.

Mr. Clutterbuck had paid much attention to the subject of the perennial flow of flood waters of the River Thames, as well as to the percolation of rain water, and its passage from the land to the river; his residence near the river Thames for more than thirty years, having afforded him a good opportunity for observation. The great body of the flood water was derived from the tributaries of the river, which, rising in the oolitic strata, received the flood waters of the Oxford, kimmeridge, and gault clays, but it was difficult to find out exactly how much rain fell upon so large an area. It had been observed that the floods in the Thames, near Abingdon, which used to reach their highest point in seventy-two hours, now reached that point in about thirty-six hours. He had noticed this for some time, and his observations had been confirmed by others. This was the case both in summer and winter, and he attributed it to the increase of agricultural drainage, within the last twenty or thirty years. Before under-drainage had been carried out to any extent, the water used to rise in the soil to the surface, and did not until then flow away down the water courses and thence to the rivers. By close observation of such facts, the truth would be arrived at. Another point worth notice was, the influence of the direction of the wind on the floods. He presumed that the theory of rain was, that the vapour was brought from the ocean —the west and south-west winds bringing the vapour from the Atlantic, and the north and north-east winds from the North Sea. In the Thames an easterly wind, with the same amount of rain registered at Oxford, produced less flood water than a similar amount with a south-westerly wind; though something was due to greater evaporation, yet this was not sufficient to account for the difference. Besides it was remarked, that the Thames stream, rising in an easterly direction, brought down more water, in proportion, with an easterly wind, than streams flowing from the westward; and vice versâ with a south, or a west wind. It would appear, that as the vapours impinged upon the land, they expended themselves either in the western, or the eastern parts of England, as the case might be, and that when they reached the midland districts, such as Oxford, they gave a mean of the rain they brought with them. Hence the necessity of consulting many rain gauges, when calculating the amount of rain which would cause a certain amount of flood water, in so large a district as that drained by the Thames and its tributaries. It required at least 2 inches of continuous autumn rainfall, such as had occurred in the month of November, 1861, to saturate the soil so as to cause the drains to discharge. It was interesting to watch the floods in the Thames, and he believed that observations of their character would be a valuable addition, to the information contained in the Paper. Although he could not, without further research, venture to discuss the difficult point of the effect of drainage on the perennial flow of rivers, he should carefully ponder over the statements contained in the Paper, and by means of other observations, would endeavour to arrive at the truth. At present it was a problem on which he desired further and more ample information.

Mr. Bidder,—President,—requested Mr. Denton to explain the mode by which the quantity of water which flowed from the land on which he experimented was measured; because, although this was only a small experiment, and thus totally inadequate to justify any general conclusions, yet every experiment which in itself was perfect, formed one of a series of facts on which some conclusions might be hereafter based. This was a question entirely dependent on facts; because, as regarded the effects of under-drainage on the general supply of rivers, there were conclusions of a general character which to some extent had been modified; or at least there were those who proposed to modify them. As regarded the effects of under-drainage, it had always been assumed that the natural effect would be to increase the floods in wet seasons, and to diminish the supply to the rivers in dry seasons. With respect to the effect in dry seasons, he had not a shadow of doubt in his own mind; but as to the effect in wet seasons, a difference of opinion existed, dependent upon carefully-observed facts. It was therefore desirable that Mr. Denton should explain the manner in which the flow of water from the land had been measured; because, from well-ascertained facts on a more extended scale, different results had been shown. At the same time it would be wrong to conclude, because one set of observations did not agree with others, that that set was not correct *per se*.

Mr. Bailey Denton replied, that the discharge was measured by having two buckets gauged and painted inside with lines, the spaces between which represented imperial pints. The bucket was gauged, filling it with water, the addition of every pint being marked by a white painted line drawn along the edge of the water received. The time was ascertained by a stop watch, the observer standing for a certain period at the mouth of the drain. This was repeatedly done, in order to ascertain with the utmost exactness the time it took for the water to arrive at a certain mark in the bucket. That the quantity recorded was accurate he had no doubt, as he stood by on several occasions while the water was being measured, and thoroughly to satisfy himself had the operation repeatedly performed, so as to be able to speak with greater precision. Not only was he present himself, but he had a letter from Mr. Clutterbuck, the owner of the estate on which these experiments were made, in which he stated that he could entirely corroborate the accuracy of the results.

Mr. James Simpson,—Past President,—remarked, that some of the conclusions put forward in the Paper were at variance with his own experience, although he believed, that in some isolated cases the proposition advanced, of the perennial flow of streams being increased by under-drainage, had been proved. Of the few instances which had come under his own observation, he would mention one, on the borders of Kent and Sussex, where the soil was a strong loam, with alternating beds of clay and retentive material, in sandy and porous soil, to a considerable depth. The extent of land drained was about 20 acres. The land rose from a stream rather abruptly, and at the bottom, contiguous to the stream, there was an osier ground, which, up to the period of its being drained, was kept wet by the flow of water from the land. Shortly after the drainage had been carried out to a certain extent, a spring broke out in a depressed part of one of the fields, and a considerable flow of water issued. It was inconvenient to allow it to remain there, and it was led away to a ditch, independent of the water course which conveyed the water from the land to the osier bed. The flow of water became a constant stream, and appeared to be much increased. At first he thought some springs had been tapped from the land, higher than that operated upon, and that the drains were conveying water from other land than that which had been drained. Subsequently, however, from a more minute investigation, he was led to believe that was not the case; and continuing the observations, he perceived in the summer and autumn that the osier bed became quite dry, a circumstance which persons who had known the spot for fifty or sixty years never remembered to have occurred before. This induced him to investigate the matter still further, and from all the trials he was enabled to make, he believed the fact to be, that during the drainage operations, the thin stratum of clay which retained the upper water, had been penetrated, and conveyed the drainage over the land, keeping it in a continual state of saturation; that subsequently the water had sunk down into the lower and more extensive porous strata, and thus had enlarged the capacity of the sandy and porous bed, or reservoir, for the reception, or retention of the water, which supplied what might be called the new spring, and by these means had increased the perennial flow of water; the new spring having, in fact, become connected with the larger and more extensive water-bearing strata.

There were other cases very much like this, in which he had no doubt, in certain years, the perennial flow was increased; but in other years, especially in seasons of extreme drought, there was no increased perennial flow of water; but on the contrary, the drought was prolonged.

He might mention a case in contradistinction to the above, at Malvern, where some drainage operations were carried on, in order to increase the supply of water to a small farm and some cottages. The springs were opened, and by that means the flow of water was increased; and the springs which had theretofore supplied the farm and cottages yielded a considerable quantity of water until about the middle of June, 1850, when they became dependent to a great extent upon storage alone. The water was conveyed into a store reservoir, holding about 30,000 gallons. At first the supply obtained amounted to 1,100 gallons per day; but in ten weeks there was no water, the reservoir having become empty, and the springs having ceased to yield any water some weeks previously. That was a case in which the effect of drainage had been to open out the springs, to drain the land, to let off the water faster, and to prolong the drought during a period of more than three months. Persons who had known the springs more than thirty years, assured him they had never observed them to cease flowing, although in dry seasons the quantity of water had been always considerably reduced.

There were many other cases to which he might refer; but there were few instances in his own practice in which the effect of under-drainage had been to increase the perennial flow. Generally speaking, he had found that the flow of water in rivers had not been increased by land drainage; but on the contrary, that in the course of years small streams had become dry which were never known to be dry before, and that the complaints of the agriculturists, of want of water on the higher lands, now recurred year after year, excepting in the wettest seasons.

Mr. JOSEPH GIBBS did not know whether the discussion was intended to be directed to the increase, or non-increase, since the introduction of drainage, of the volume of water in rivers, or whether it was only intended to elucidate the advantages of drainage generally, and its effect on the outfalls in particular. Looking at it, however, as a question of general drainage, he would offer a few observations on that division of the subject.

From his experience and observation, he could only arrive at the conclusion, that it was almost impossible to generalise with regard to evaporation, because the effects were so various, and the disturbing causes were so numerous, that results were difficult to arrive at. As an instance:—If water was exposed to the action of the air, the evaporation would be in excess; but, on the other hand, if evaporation took place in a field covered with vegetation, it would be at a minimum. Those cases occurred so continually, that the amount of evaporation from the surface of a large area of land, when considered with regard to the rainfall, could not be ascertained with accuracy.

He did not notice that the question of capillary action was touched upon in the Paper. If the drainage was too deep, the capillary action was weakened. If the drainage was not deep enough, the penetration of the air was not sufficient for good cultivation. His attention had been drawn to these questions for more than forty years. In his early days he had studied under Dutch Engineers, and had been taught by them valuable lessons in drainage; and the whole of his experience from that time to the present convinced him, that the Dutch system of drainage and of preventing the water from sinking too low, was the correct mode of treating land.

Touching this question he might, perhaps, be allowed to relate an experiment which he had tried some years since, and which bore upon the effect produced by drainage. It was this:—He had a cistern of large size constructed with a material of a porous nature, like drip-stone, and of the depth of 2 feet 6 inches, in order to assimilate to that of an ordinary Dutch drain, which was from 2 feet 6 inches to 3 feet. Water was admitted by the lower part of the cistern, to represent the subterranean water surface, after drainage had been completed. The earth put into the cistern was the ordinary soil of a wheat field in good cultivation; vegetables, grain, and trees were then planted in it, and all flourished and grew luxuriantly. Another cistern was made in precisely the same manner,—the same conditions being observed, with this exception—that to this cistern there was an outer case, and that water was admitted between the internal and external cases, so that, instead of descending in the ordinary way of rainfall, it ascended, and was then evaporated from the surface of the soil. In the latter cistern various descriptions of aquatic plants and mosses were placed, and they all flourished, no air descending into, or mixing with the soil. After those crops were grown the operations were reversed, and the aquatic plants died, because the air penetrated downwards: whilst all the cereals and other useful plants perished in consequence of the water ascending. In the latter case it was evident that there was no capillary operation going on. This in one case was the condition necessary to create a bog, and in the other to occasion those operations of nature which always produced fertility. The importance of the air descending into the soil, in order that it should commingle with the moisture derived from capillary attraction, need scarcely be dwelt upon. But the usefulness of such an adjustment of the water-level did not depend on the evaporation of the water alone. The water evaporated by capillary attraction always left behind it a certain portion of sustenance for the plant; because by evaporation from the surface pure water alone was abstracted, leaving the useful materials brought up from the lower stratum for the sustenance of the plant. It was in that way, and where the water instead of being fertile was chalybeate, that the 'pan,' as it was called, found upon poor sandy soils, was formed. The capillary operations before described, left behind a material which produced the pan, or rough conglomerates, cemented with iron; and where that was the case, no useful culture could be carried on, until that pan was removed. All these details were of great importance. The general conclusion he had arrived at was, that drainage might be too deep, but it was indispensable to have it deep enough. Questions of this character could not be reduced to any rule, inasmuch as the depth of proper and judicious draining was dependent upon the nature of the soil. Still, even taking into account the nature and character of the soil, the probable changes after drainage, and other circumstances, the limits were not very great between deep and shallow draining. There were as many advocates for deep draining as for shallow draining; but at the same time, it must be observed that, throughout the Low Countries, where the open drain represented the most perfect system of drainage, the fertility of the land was primarily dependent on draining; and there the water was rarely below 3 feet from the surface, in consequence of another operation much connected with this, namely, the operation of sub-irrigation.

Great improvements would doubtless be induced by the recent legal enactments, in providing proper outfalls and recovering large tracts of land from the state of swamps. These proceedings would be the means of regulating the courses of rivers; but at the same time there was no doubt that all these improvements would, by cutting off bends and making other alterations, bring the flood water more rapidly down the streams; nevertheless the general character of the rivers would be ameliorated, so far as available water for mill purposes was concerned. It was also important to look at the question of good outfalls on the sea-coast, because in flat districts great benefit might arise from attending to the marine outfalls. He thought that outfalls were too often referred to the contiguity of older works, instead of establishing good parallel outfalls, independently of the existing rivers. Nearly all the outfalls in the Low Countries were independent, were parallel in their sides, and did not open out into estuaries. Attention should be directed to that question, and it would be well that inquiry should be made as to where the sea outfalls might be best located. He was strongly inclined towards the adoption in all cases o. a parallel exit, excluding all river water when charged with earthy, or sandy matter, and also excluding to a considerable extent the tidal inflow.

In answer to a question from the President, Mr. Gibbs said the standard depth of draining in Holland, in order to maintain the water in the drains below the level of the land, was 2 feet 6 inches, or 3 feet; but that was not a fixed rule. The water was sometimes raised 2 or 3 inches in the summer; and on meadow land, in winter, it was often raised above the level of the surface of the ground, for if a farmer got his land covered with water in the winter, and it became frozen, a certain amount of subterranean heat was preserved, and retained in the ground; and it was calculated that earlier crops were obtained by retaining that warmth.

Mr. Evans had not had so much experience in clay countries as in soils of a more pervious character. The subject of discussion might be divided into two heads—first, the experiments themselves; and secondly, the deductions to be drawn from the experiments. Mr. Clutterbuck had corroborated Mr. Denton's remarks as to the care with which these observations had been made; but still there were probably many sources of error which might arise in an experiment of this kind, extending over a period of only eight months. In the first place, the effect of draining heavy clay soil was not immediate. It was some time before the drains got into operation, and a certain period must elapse before all the channels which opened out to those drains were fully formed. He was not aware how long the fields had been drained previously to the experiments being made, but he believed that the drainage had not long been completed. Another question which might interfere was, whether the land was lying fallow, or was covered with vegetation. A crop of turnips would in the autumn months absorb moisture, which under other circumstances would have gone into the ground, and even a crop of grass might affect the penetration of the water into the soil. It had been said that in these eight months there were only 10 inches of rain. Mr. Denton had stated that the average rainfall in that district was 13 inches. He thought they might assume, if 13 inches had fallen, the other 3 inches would have found their way down to the drains. But it was shown by Dalton's gauges, which Messrs. Dickinson and Co. had kept in operation for thirty years, at Nash Mills, that with the same amount of rainfall there would be different penetration in different years. Much depended upon the manner in which the rain fell. During slight showers, with fine weather intervening, there would be little penetration; but with heavy rain day after day, the ground would be saturated, and a great quantity of water would go down to the springs. In the years 1856-57, during the six winter months of October to March inclusive, a period which corresponded with six of the eight months to which these experiments referred, 11·96 inches of rain had fallen, and yet only 3·72 inches passed through the gauge, filled with ordinary surface soil. In the winter of 1857-58 there had fallen 11·81 inches of rain, and as much as 5·64 inches passed through the same gauge; showing clearly that the penetration into the soil depended upon the manner in which the rain fell. In the winter of 1858-59, with a rainfall of 9·64 inches, less than one-tenth of an inch passed through the soil to a depth of 3 feet. It was therefore obvious, that a great range of experiments was requisite to obtain satisfactory general results. Mr. Charnock had stated that the annual evaporation from a saturated undrained soil was 8 inches more than the rainfall. Practically, there would be difficulty in getting that amount of evaporation, as more water could not be evaporated than had fallen in the shape of rain; but, after all, in cultivated soils, it was not so much a question of mere evaporation from the surface, as of the absorption by vegetation in summer. Mr. Lawes had shown that a grain of wheat, in growing to maturity, would take considerably more rain than its share, if it could get it; and in the summer months in free soils, on which vegetation was in progress, there was little, or no penetration through the soil. Scarcely any moisture would go down 3 feet, so as to reach the springs. It appeared to him, that deductions arrived at from such slight experiments as those of Mr. Denton could hardly be relied on, and it would be safer to trust to careful observation and general theory. The object for which the drainage of clay soils was undertaken was to convert heavy, impervious land into free soil, and to make it assume the same conditions as if it contained a large amount of arenaceous matter. The consequence of drainage was, that the land was more easily broken up, because it had become more friable, and was more pervious to air and moisture. But still there was a vast difference between the two characters of soil. Generally speaking, where free soil existed on the surface, it had a substratum of sand, or chalk, or other analogous formation, forming a natural storehouse for the water accumulated in it by percolation during the winter months, and that water was gradually delivered out in the summer months. In the case of a clay soil there was nothing of this kind, though there were frequently small spongy reservoirs on, or near the surface, from whence, however, there would be but very little flow in the summer months. In undrained heavy soil there were found springs of that kind, and it was mainly upon them that the rivers were dependent for supply, in addition to what might be derived immediately from the rains. The consequence of the clay soil being converted by drainage into a friable state would be, that in the summer months much more rain would be absorbed. It would take in nearly all the rain which fell, and would retain it for the purposes of vegetation; whereas in undrained clay soils the surface was cracked and fissured to a considerable depth, while the clay itself was comparatively as hard as a brick; and if a heavy rain fell upon the land in that state, a large amount of it was carried off to the rivers. His impression with regard to the drainage of clay land was, whatever might be the effect upon the floods in winter, and these would probably be increased, that in the summer months the flow must be diminished, and the irregularity of the flow of the streams, which was already too great, be rendered greater still. If the system, now so commonly pursued by Local Boards of Health, of converting rivers into common sewers, were persisted in, any diminution of the flow of the rivers, during the summer, would be attended with incalculable injury to the country.

Mr. R. B. Grantham considered the Paper was of great importance, as affecting a subject in which he had taken some interest, that of arterial drainage and outfalls. With regard to experiments in pipe draining, so few had been made, that they could hardly be trusted as grounds from which to draw any correct inferences. There were several localities which he could point out, in which it would be very useful that such experiments should be made. He might instance the Hainault drainage, which had been carried out by himself. The pipe drains in that case were conducted into the main arterial stream, the natural inclination of which would have caused far too great a velocity in the water flowing through it, had it not been checked in its course by a series of overfalls, below each of which the pipe drainage was brought out. A good opportunity for observation was thus afforded. These main pipes coming out at the overfalls drained a certain defined area on each side of the arterial stream; and proper rain-gauges being kept and observed in the locality, the exact discharge at each place might be ascertained, and compared with the rainfall. He hoped the new Drainage Act, in which he had assisted the Government, would prove of great advantage to the country. As yet they could hardly tell what its effect would be; but it might fairly be expected, that there would be a great opening for the engineering profession. The cases which would arise would require a peculiar kind of operation, more particularly with regard to the large tidal rivers. It still remained to be ascertained, how under-drainage would affect the rivers between the tidal level and the upper country, where the water would be sent down in great quantities by the improved formation of rivers, and from the pipe-drainage system.

Mr. EDWIN CHADWICK, C. B., would attempt very little on the mere technical portions of the subject. But the course of the discussion displayed wide differences of opinions, which might be ascribed to the different points and comparatively limited areas of observation, and to differences of conditions, such as must occur even to professional men of wide practice in drainage works. It appeared to him, that wheresoever the future was charged for results, or where absentees, or reversioners were made liable *in futuro*, or where public money was expended in works, there ought to be an independent examination of the works, as well as an audit of the expenditure, to verify the fact that they were of a quality to insure, and to be of benefit equivalent to, the charge upon future as well as immediate contributors. Several millions of public and private money had been expended on works conducted on different methods and conditions. He did not mean to suggest that such an examination as that which he advocated, as a matter of principle, was needed in this case, on account of any malversation, or malpractice—for he had heard of remarkably little absolute failure—all, speaking generally, appeared to have been successful, though in different degrees. The earlier and ruder works had generally repaid the outlay in about ten years; the later, and better works, usually in about four years. Yet only a small proportion of the lands which required drainage had been drained, and a proper examination would tend to reassure and encourage owners and occupiers, and would, moreover, serve to show which of the various methods in use was the best under the like circumstances, and much would be learned for the improved direction of the large amount of future expenditure required. There were large agricultural facts as well as engineering facts and laws to be determined. For agriculture, the purpose of drainage was not to render land dry, but to regulate and adjust its moisture, commonly and generally by the removal of the excess of water; and it would also be frequently found necessary, at particular seasons, to supply deficiencies of moisture. He had long been told of facts such as those mentioned by Mr. Gibbs. In some of the fen districts it had been ascertained, that when the water table was maintained by pumping a few inches below, or above given points, too much, or too little, was done for certain cultures. The determination of such facts would be of agricultural importance. On the other hand, in works for the subsoil drainage of the sites of towns, where in order to prevent damp the object was to render the sites absolutely dry, in carrying drains, or sewers, through suburban, or market-garden cultivated land, there had, at some places, been outcries from the gardeners that they were injured by too deep drainage. On sanitary, as well as on agricultural grounds, he had recommended the abolition of open ditch drains, and the substitution of pipe drains for roads, as well as for fields; providing cess-pits, in the roads, for arresting the detritus. In most cases the surface of ground gained paid for the substitution. The experience of this description of road drainage would show, where it was properly conducted, that whilst it was best for the roads, it also served to provide outfalls for the subsoil drainage of the adjacent cultivated lands; and where the roads and public paths were close, in some strata, it did, for the adjacent cultivated land, almost all the work of drainage which it required. With respect to the question of outfalls, it would be found, as had been proved on some estates, where absolute marshes and swamps had been drained, that for advanced culture, and for the most active growth of vegetation at particular periods, as well as for the cheapest and most efficient distribution of manures, all the rainfall of the year would be required that could be detained for application by storage. As to the effect of the excess of moisture in lowering temperature, there had been important experience of the effect of its removal in elevating it, which seemed to him to warrant the expectation, that if the land were generally and systematically drained, an elevation of some six degrees beyond the present average temperature of the country would be the result. There was, moreover, important experience to be collected from the improved adjustment of the sizes of small, as well as large pipe drains, to the service for which they were required. The drainage works of the larger proprietors, such as the late Duke of Portland, the present Duke of Northumberland, who had for some time expended as much as £20,000 a year on land drainage, and others, had been conducted under very intelligent observers, who could contribute highly valuable information. A proper inquiry, conducted by intelligent, impartial, and competent persons, could not fail to be productive of useful information for future guidance, and would probably provide a basis for the deduction of general laws, for which the scattered and fragmentary details now possessed, or obtainable by casual volunteer efforts, appeared to be wholly inadequate.

Mr. **Samuel Sidney** would make a few observations on the agricultural element of the subject. Up to the present time the question of drainage had not been of sufficient importance to attract much attention from the higher members of the engineering profession; but the statements of Mr. Evans showed, that at no distant period the accumulation of surface waters, rapidly poured into the brooks and rivers, would be so great as to require the best energies of the rising generation of Engineers. Facts were not wanting to point out how rapidly this period was approaching. Only about twenty years had elapsed since the attention of agriculturists was called to the principles of systematic drainage, and it was only about seventeen years since the horizontal machine for making drain-tiles, and which first provided cheap tiles, was invented.

It was about fifteen years since the Act for the first drainage loan of £2,000,000 was carried by Sir Robert Peel's government. That loan had an extraordinary effect, in first converting landowners and then tenant farmers to the new principles of agricultural drainage; but what might properly be called the 'Parksian' system had only been freely accepted by tenant-farmers during the last ten years. Within Mr. Sidney's recollection the subject of discussion at the farmers' clubs was, not whether the draining should be shallow, or deep, but whether land should be drained at all. At the present moment a farmer would not look at a clay farm, unless the landlord undertook to drain it thoroughly. In the course of the last fifteen years 1,000,000 acres of land had been thoroughly and systematically drained. There now remained about 21,000,000 acres of land that would pay for the cost of draining. It must not be assumed that the future operations would be carried on at the slow rate of the last fifteen years. At the commencement of that period, there were extraordinary difficulties to be overcome before agricultural land could be reduced to the more profitable condition of dryness. In the first place the greatest difficulty lay, as he had before observed, in the prejudices of the landlords and the tenants: and here he might observe, in reference to what had fallen from Mr. Gibbs, that the practice in the Netherlands did not bear much reference to what was required in the great corn-growing districts of England. In the most pressing cases, they had in this country to deal with stiff clay soil, and they wanted to make it a free soil, to get rid of the rain and the springs fed by the rain. In the Netherlands they were generally compelled to grow such crops as would flourish on a rich damp spongy soil. Having convinced the minds of the people, the deep drainers had next to get the money,—at the rate of about £4. 10*s*. per acre. Government had lent £3,500,000 on annuities, which amount was in course of repayment; Drainage Companies had been formed which had lent £1,500,000; and the large landowners of the country, who had ready money to spare for investment, had been enabled, by a special act, to charge the money spent on draining entailed estates, with the repayment, for the benefit of younger children, or other legatees. The moral, the pecuniary, and the legal difficulties, having been thus diminished, it might fairly be expected, that in the course of the next fifteen years, a large proportion of the twenty-one million acres, still remaining, would be thoroughly drained. Thus it might be expected, that the surface waters would flow each year more rapidly and in greater quantity into the rivers, and that damaging floods would increase in number and extent. He had lately visited a part of the country which had always suffered from floods, and where the oldest farmers agreed in stating, that the floods became every rainy year more frequent and more injurious, because they came on more rapidly. Within the last two years steam cultivation had added another powerful stimulus, not only to drainage, but to the flow of water through the soil. Three, or four years ago, few persons believed that steam cultivation could be made profitable, but at the present time between three hundred and four hundred steam cultivators were at work, and the manufacturers were delivering them as fast as they could be constructed. The first effect of steam cultivation was to bring retentive clay soils into favour. These clay soils could thus be turned up five or six inches deeper than had ever been done before. With steam cultivation clay land was brought to a condition in which it parted freely and easily with the rainfall, allowing that portion of it to run into the drains, which was previously retained until evaporated. The action of the measure for improving arterial drainage, which was passed by Parliament during the last session, depended on the opinion of a majority of landowners; but landowners were not

Engineers, and therefore useful facts, on the subject of arterial drainage, must in some way be communicated to them. A professional investigation, geographical and geological, of the condition of the water courses and outfalls of the kingdom was imperatively required. At present landowners had often nothing better than the vague ideas of uninstructed people to act upon. He knew that commissions were not very popular,—they had deservedly acquired a bad name, from the way in which some of the early ones had been worked. He thought it must have struck impartial lookers-on as very odd, that while English Engineers were confessedly the first in the world, the Government rarely consulted the Institution of Civil Engineers, whose Council included all the most eminent men in the profession. This question of agricultural and arterial drainage was one which the Government might entertain if they selected competent advisers. He made these observations solely with the view of showing, that the works, about to be required for completing agricultural drainage, would be worth the attention and would pay for the services of the rising generation of Civil Engineers.

Mr. Gibbs said, the systems of agricultural drainage in Holland and in the stiff clay districts of England differed essentially; but the operations of those physical laws, by which the admission of air into the soil, and the extraction of water from it, were effected, were the same, whether they were performed by pipe draining, or by open draining. It must be considered for what purpose drainage was carried on in a stiff soil. When by the effect of drainage the air was enabled to penetrate into the soil, the soil itself changed its character. It would then hold only what might be termed the normal quantity of moisture, which was, really, the exact amount of moisture fit for agricultural operations and for the development of vegetable life; but clay soil, unsubdued by the effect of draining, held more than its normal quantity of moisture, and might be considered as being supersaturated. Draining rendered it only a moist soil, and the object of draining was to obtain land fit for agricultural purposes. He had seen evidences that clay was pervious to water in summer time, having traced small veins and openings caused by summer shrinkage to a depth of 10 feet, or 12 feet below the surface of the earth, and it was in such cases that nature performed the operation of causing the air to enter into the soil; but it came too late in the summer season for the purposes of vegetation. By draining the same clay soil, rain, air and heat were constrained to penetrate the earth, and thus to change and ameliorate its nature, by which means the advantage of an early season was attained.

Sir John Rennie had not been able to collect the whole of the facts mentioned in the Paper, so as to express an opinion on them. Upon the agricultural portion of the subject he would not offer an opinion. With regard to the outfalls, no doubt the improvement of them, in districts through which large masses of water passed, was extremely important. He had been engaged in conjunction with his late friends, Mr. Telford and Mr. Robert Stephenson, in extensive works, in connection with the drainage of the low Fen districts adjacent to the Nene, the Ouse, the Witham, and the Welland, and in some of those cases the water had been reduced to 3 feet below the surface, which was considered sufficient. The important point, on which, as Engineers, he trusted they would agree was—that the getting rid of the water was not the only important part of the question, but that in all districts, where there was superfluous water at certain periods of the year, they should have a command of it, and not only be able to drain as low as was necessary, but to possess the means of employing the water for purposes of irrigation, when it was so required. In particular districts there was only a certain amount of rainfall, and this occurred chiefly during the autumn and winter. If the whole of that water was discharged at these particular periods, during summer, when there was less rainfall, water might be wanted, which frequently occurred. The object, therefore, of all drainage was to have a perfect command of the water; or in other words, they should have the means of getting rid of it to as low a point as was required, but at the same time they must have the power of supplying water when it was wanted for cultivation and for other purposes during dry seasons.

Mr. Robert Rawlinson thought it very desirable, that they should be informed what crops were grown on the land which had been the subject of the experiments referred to. He had been informed, that according to the experiments of Mr. Lawes, in order to grow one pound weight of true woody fibre, two hundred pounds weight of water must be evaporated by the growing plant; and if drainage improved the land in one respect, by causing increased power of growth in plants, it also brought into operation a greater power of evaporation; and therefore it would be useful to know the kind and weight of crop that was grown on drained land. There was one fact, regarding the question of rainfall, which came under his notice during the previous week. The year 1861 was an exceptional season; and at Seathwaite, in Cumberland, up to December 5th of that year the rainfall was stated to have been 171¼ inches; during November it was stated to have been about 35½ inches. At Keswick, only 9 miles distant, it had been about 13¾ inches. That was the heaviest recorded rainfall that had occurred in that district for fifteen years. As to obtaining a command of subsoil water, it occurred to him, that on large estates having a good fall, the upland subsoil waters might be utilized, and not as at present be passed directly away into the outlet. If large districts were properly laid out, the upland waters could be made to irrigate the lower-lying land, down to the lowest point. Parallel drains and reservoirs might economise drainage water, so as to be made to cover terrace after terrace of any adjoining lower lands.

Mr. G. W. **Hemans** remarked, with reference to the question of the increased flow of rivers from drainage, that extensive operations had been carried on in Ireland with public money. Unfortunately, the works had not been judiciously laid out, and disappointment had resulted. It was therefore desirable, that any measures which might be thought advisable in England should be conducted in a different manner. It was notorious, that the waters in the great valley of the Shannon had been much increased by the flow from the uplands. Shallow lakes and bogs, presenting large evaporating surfaces, had been drained, and had ceased to exist, and the upper lands were therefore improved, but of course more of the rainfall came down to the river. At the same time the bed of the river had been improved, and efforts were made to preserve the navigation, and to provide for the increased discharge of water from the uplands; but it had hitherto been found impossible to do so adequately, so as to meet the discharge from the upper country. A public meeting had been lately held, for the purpose of requesting the Government to remove weirs and to construct other works, in order to provide for this increased discharge of the upland waters. As far as his experience went, he had no doubt that the flow of the river had been increased by the drainage of the uplands.

Mr. T. **Hawksley** did not think, that agricultural drainage was a topic which particularly interested a great number of the members of the Institution; but he believed that, at no distant period, many Engineers would be engaged in practical operations under the provisions of the Act of Parliament passed during the last session, known as "The Drainage of Land Act"—an Act of momentous importance, which would not only create a great revolution with regard to the present exclusive rights in landed property, but would also extensively affect the public rivers of the kingdom. Therefore, under these circumstances, however small might be the general interest which attached to the questions directly raised by the Paper, it was certain that all Engineers had, in the future dispositions which might be needed under this first parliamentary enactment, a great and special interest.

The Paper had touched upon almost all the subjects on which the agriculturist could be called on to express an opinion. Mr. Hawksley, therefore, would rather draw attention to those large engineering and physical features which interested Engineers in their practical dealings with rivers and outfalls, and the influences which affected the course of their flow,—of rivers and their ordinary volume—their augmentation in floods—their diminution in droughts—and their mechanical agency.

The Act recently passed, was one which would more or less, according to the extent to which it might be carried out, seriously affect all the rivers and streams of the kingdom. It was no less than an Act to empower certain commissioners to deal with all the sources of water in the kingdom; and it proposed not only to give power over all streams, but also to confer, by a certain process, and that a very rapid one, the right on a public Board to remove mills, and to destroy mechanical power, in a way which, he believed, had never been practically attempted before.

The Paper had brought some apparently important experiments before the Institution. They were not important because of their magnitude, nor because of their general application to the condition of the water sources in all parts of this kingdom, but because they seemed to initiate a method of treating the subject which must be considered as in some respects fallacious, and, therefore, it was desirable, on the threshold of the inquiry, to express an opinion on that subject, lest it should be said that this Institution had concurred in the views which the Paper had enunciated. Mr. Hawksley did not mean to say that, in the particular case which Mr. Bailey Denton had introduced, he had made mistakes, or had drawn erroneous conclusions; but he did mean to say, that the instance was a very exceptional one, and that general conclusions drawn from such an instance would lead to great and important mistakes.

The instance which Mr. Bailey Denton had given was that of a portion of a farm at Hinxworth, in the neighbourhood of London, and he had drawn his conclusions from the fall of rain in a somewhat exceptional year, upon a surface partly of chalk, and partly of green sand, with also, as he understood, an outcrop of gault clay. It appeared that these experiments were made in the winter months, between October and May, in the year 1856-7. Now it so happened that in those months there was comparatively little evaporation, while the months in which there was the greatest evaporation were entirely omitted. Moreover, that was a year in which the rainfall was considerably below the average; and, taking these two circumstances into account, the deductions drawn by Mr. Bailey Denton, with regard to ratios and proportions must, he thought, be deemed erroneous. Besides, these experiments were made in a part of the kingdom where there was almost less rainfall than in any other locality, excepting in the Fen districts and the extreme east coast. The consequence was, that any conclusions drawn from these data would not apply to at least three-fourths of all England; for while, as a rule, the evaporation from the surface of ordinary land, in the latitude of 52°, might be taken to be about 14 inches, and the rainfall in the centre of England and in the same latitude at only about 24 inches, leaving about 10 inches ordinarily to penetrate into the ground and to flow off by the surface, on the western side of the kingdom the rainfall was from 36 inches to 50 inches, whilst the evaporation was no more than at Hinxworth. By penetration into the ground he meant penetration into a chalk surface; and of course in other places where there was not chalk, or an equally open soil, a part penetrated into the ground, and a part passed off as surface water. But in the parts of the kingdom to which he alluded, large portions of the water, perhaps as much as 3 feet in depth, would partly penetrate into the ground, and partly—the greater part indeed—flow off by the surface.

The ordinary conditions were, therefore, very different from those expressed in the tables given in the Paper; and in drawing general conclusions from these limited experiments, he was afraid professional men would commit considerable errors in their practice as hydraulic engineers.

Then, again, there were great differences of rainfall in different years. In some years the rainfall was a minimum, and was not more than half of the maximum, but the penetration into the ground would not greatly differ in the two states of circumstances. He did not say it would not differ, but in many soils it would not greatly differ. It was known practically, that in large portions of the west part of the kingdom, nearly all the water ran off by the surface, the volume of spring water being quite insignificant —not a 10th, a 20th, or a 30th part of the rain that fell. Under those circumstances, the tables given would lead to erroneous conclusions.

The Paper had also directed attention to this fact, that under the new Act it was proposed, and under the operation of that Act it would be effected, that large areas of ground, according to Mr. Bailey Denton, as much as 23 millions of acres, would, in some way or other, be dealt with by under-drainage. It was assumed that this operation would either not destroy the rivers, or that it would improve them. Now, Mr. Hawksley could only understand rivers as being 'improved' when they were rendered steadier, by the water being made more capable of being utilized, either for mechanical, or other practical purposes, or by being better fitted for navigation, or by being in some other respects made more useful. He believed the experience of all who had been engaged in practical operations connected with the collection of water was this, that the more the land was under-drained, the more the irregularity of the streams was increased. He did not mean to say that there were not exceptional circumstances, and that cases might not be pointed out, where the contrary might be the result, in a particular soil which should receive a large volume of rain-water rapidly and give it out slowly. There were, indeed, cases of that kind in the vicinity of London, in which the chalk received large quantities of water, in wet seasons especially, and which gave it out slowly by the springs. That, as a matter of course, was a condition under which the natural under-drainage of the chalk improved the régime of the river; but the circumstances would be very different, under any other condition. Let the case be assumed of land being so under-drained as to make it capable of receiving water more rapidly, and that by this underground communication, the water was enabled to get more quickly away. The consequence would be, that the operation would contribute largely to the volume of the rivers for a short time, until the soil was exhausted of the redundant water. Under these circumstances, the river would be filled to overflowing at one period, and at another period the same river would be in a state of extreme and long-continued drought. That was a condition, which would neither be good for mechanical power, nor beneficial to navigation; and as regarded the landowner, it was manifestly often worse than the previous condition, because there would be floods on low lands, where there were no floods before, and droughts on high lands where a certain quantity of water should be kept for the supply of cattle, and for agricultural purposes. He could also state this broad corroborative fact, that within the comparatively short period of his own experience, as an Engineer, a perceptible change had taken place, as it had now become necessary to make larger reservoirs for the collection of water for the supply of towns in drained districts, and to hold a greater supply than had been requisite twenty, or thirty years previously.

There was also another condition of things worthy of serious consideration. Was nearly all the mill power to be taken away? He might state, as a curious fact, that proposals had already come before him for destroying mill power under this Act: though it had not yet been put in operation, landowners were already proposing to avail themselves of the powers of the Act against their neighbours; and therefore he was in possession of some of the results to be brought about by the Act when it came into operation. This was the state of circumstances as to the mill power of England. Just now it was, or very recently it was, at what might be termed its minimum value, and that had been in a great measure owing to the undue and excessive quantity of coal which had been raised. But whilst there had been so much coal raised for home consumption, enormous quantities had been sent abroad, and there had been lavish use of it in manufactories and in private families. There were now raised and used more than 100 million tons a year, and that quantity was continually increasing. The result must, however, necessarily be, that all the cheap beds of coal would be speedily worked out, and that the price of coal would be greatly increased. It was already increasing slowly but steadily, and he believed from the cause he had mentioned, viz., that in many cases the cheap seams had been worked out, and that consequently deeper explorations had to be made at greater cost to the mine-owner.

Under these circumstances the water power of the kingdom would become more valuable. He did not say speedily; for he was looking at the question in a national point of view; and he thought it was a duty to conserve the water power of this kingdom, for the many purposes for which it would be wanted in the course of another half century, and especially in operations more, or less directly connected with agriculture.

There was a provision, in this Act, of a most curious kind. It might be said that it had followed a precedent, but when was the precedent created? Only during the previous year; and the peculiarity was this—that the Act might be brought into operation at the instance of the few, while the defeat of the attempt to bring it into operation could only be by the combination of the many. The Act having to be carried into effect, in this peculiar manner, under the sanction of a central board, it might be presumed that it would be put into general operation, and no doubt the Engineers would be largely engaged in these matters—either on one side, or the other. The course of proceeding was this: The Act might be proposed to be brought into operation for the purpose of removing mill-dams, weirs, and other like "obstructions:" this was going a long way, as anything might be called an "obstruction" which interfered with the run of the water. How was this generally to be dealt with? In this way—the objecting party was first to submit to an arbitration on the question of "principle." He was to submit to two arbitrations, and to bear many of the costs of the two. He was first to have an arbitration upon the principle, whether, for instance, his injury was capable of being compensated by money: not the price to be paid. He should like to know (with one, or two very exceptional things) what case there was which could not be compensated by money. The consequence was, the principle on this point must in general be decided against the objecting party. Then he was to be subjected to the tender mercies of another arbitration, which was to be conducted under the Lands Clauses Consolidation Act, to ascertain what remuneration he was entitled to receive, for, it might be, the entire destruction of his property. Now he believed the system of arbitration, as arbitrations were usually conducted, was the most expensive engine known to the law of this land. He had himself been intimately connected with arbitrations of the most absurd and cruel kind. The last was of this nature. He would not give names, nor cite the instance except in its results. A claim was made for a large sum:—£20,000. The claim was disputed, and the case went to arbitration, in the manner provided for by the Lands Clauses Act. It was referred to two arbitrators with an umpire, who was a legal man. The result was an award of £3,000, the costs on one side being £8,000 and on the other side £5,000. Now he thought an Act which was to be brought into operation in the manner he had stated, with two of these engines set to work upon the poor resisting proprietor, was very likely to kill him outright.

But there were more serious matters, in other respects, than even those which he had mentioned. Under the operation of this Act, if a gentleman wished to drain his land, that land having been purchased at a price due to its unsatisfactory condition, he said, "I cannot make the best of my land, for which I have paid such a low price, unless I can do something with my neighbour below to compel him to let my water run through his property." The man above then set this Act in motion, and under its powers obtained a right to a new and legally created servitude in, or over the land of the owner below him. Mr. Bailey Denton would probably say, "We must drain in the manner pointed out by this Act." He dealt with no less than 23 millions of acres: but in different ways. He estimated that 11 millions had retentive soil, and they were to be dealt with by pipes which were to be laid at distances from 25 feet to 27 feet apart over all those acres, and that there were 12 million acres of what was called free soil, and these were to be dealt with by a disposition of pipes at uncertain intervals and at considerable depths. It had been said that by lowering the water in the Fens to a depth of 4 feet, the cultivation would be improved. Now Mr. Hawksley had incidentally something to do with the cultivation of the Fens, and he knew that in large portions of the Fens it would be very detrimental to lower the water in dry summers below 30 inches from the surface. He did not say that this was universal, but over a large area of the Fens that was known to be the fact. At present the farmers had to sink down 7, 8, 9, 10 and sometimes 14 feet, to bring up marl to spread over the surface of the peat, for the purpose of consolidating it, and rendering it capable of retaining moisture. And then what happened? In the course of two, or three years the marl was found to have gone down the depth of a foot, or more, and it went on sinking, in the course of years, to 6 or 7 feet deep, and then the process was to begin the work over again. Of what use then, he asked, could this species of drainage be there? Only to make the superficial soil drier and lighter than it was at present. Taking, for instance, the land from Spalding towards Boston, this species of draining would be of no use. It would in fact be seriously injurious, for all that was necessary was to keep the water just low enough to allow the surface soil to become warmed by the sun, and just high enough to feed the plants with the necessary moisture, by capillary attraction from below.

Then, with regard to a large portion of Cumberland—the mountain land which there laid upon rock. Of course the species of drainage recommended would be of no use there—and so he might say of a great many other instances which occurred to him: he said nothing against Mr. Bailey Denton's theory of drainage, as applied to tracts of land for which it was fitted, but he objected to it as a general proposition, and therefore as a method to be applied to many other kinds of land which must be included within these 23 millions of acres.

Then as to drainage by pot pipes: that was an excellent mode of drainage in general, but it was attended with difficulties in particular cases, and it was frequently not so perfect as many other modes, better adapted to the resources of particular districts. In some cases when draining to the great depths, advocated by Mr. Bailey Denton, the expense became too great for many millions of acres included within the assumed area. If, on the other hand, the drains were shallow and the drain-pipes were small, the roots of the plants would get into them and would spread there like a seaman's swab, and in consequence the work would soon fall, and would have to be done over again. Therefore, he contended, that this sort of uniform operation would not answer: he did not say that he attacked it—but he endeavoured to express himself thus, at this early period, to prevent any general system, or code being adopted, or recommended by a Central Board, and so being carried all over the kingdom. What he contended for was, that every Engineer should be left to the unfettered exercise of his own skill and judgment, in all these cases, in order that he might advantage his employer, to the best of his ability.

He wished now to add a few words on the general engineering question; and knowing how difficult it was to deal with figures, in a discussion of this description, he had prepared a diagram, which represented what he believed to be some important facts with regard to the rainfall and evaporation, and the quantity of water flowing off large areas of land, on the western side of the kingdom; and what he was now about to say would apply, in a greater or less degree, to certainly 12,000 square miles, or 15,000 square miles of the area of this kingdom. In this diagram there was recorded, by blue lines, the average amount of rainfall for every year, during a period of thirteen years, and by red lines the amount of loss by evaporation, and the distance between the red and the blue lines represented the quantity of water which ran off the ground. The Paper referred to a case in which the rainfall for eight months was stated to have been only 10 inches, and probably in that year the rainfall for the whole twelve months did not exceed more than twice that amount. In the case alluded to the average rainfall was more than 4 feet, and from year to year during the whole of the thirteen years, it fluctuated very greatly; but, on the other hand, the amount of water evaporated from the surface of the land was much more nearly uniform; and what would appear surprising at first was, that in the driest years the evaporation was the least. That arose from the fact, that although the power of evaporation was then the greatest, yet the water was not present to be evaporated: and the consequence was, that evaporation in the dry years was less, considerably, than it was in the wet years. Now in this case it was necessary to provide for carrying off more than three-fourths of all the water that fell, and that too principally by the surface channels; for it was impossible in a case of this kind that, by any means of under-drainage, the water should be let down below the surface of the earth so rapidly, as that a large portion of it would not flow off by the brooks. The inference, then, to be drawn from this was that Mr. Bailey Denton's data, valuable as he admitted them to be, with reference to chalk districts, were not generally applicable over the whole surface of the kingdom.

Then as to the question of mills. If the process recommended in the Paper were to be brought into effect all over this kingdom, the result would be that, for the sake of very minor interests, nearly all the water power would be destroyed. Much of it was now exceedingly valuable; and it would become more so as coal became dearer. Even now in the less accessible agricultural districts, it was almost indispensable for grinding corn, and for other similar purposes.

The process which Mr. Bailey Denton desired to bring into operation was, not only to make the pipe and other drainage relieve the land, but also destroy the mill dams. But on the other hand, what Mr. Hawksley insisted upon was, that it was wholly unnecessary, in the majority of instances, to adopt such a course, because, as compared with the large areas of the country, the tracts that were affected by mill-dams were very small. Assuming that, in some instances, the water was raised by the dam above the adjacent land, and that a few meadows and low-lying lands were affected; it was quite clear, that in the majority of these instances, the drainage might be effected, independently of the mills, by making side-drains, and carrying the water below the mill-tails. All he wished to express was that, inasmuch as an Act had been passed with extraordinary powers—such powers as had hitherto not been known in English laws—that those powers should be carried into execution with great discretion, and with a due regard to the great present and prospective interests which were liable to be affected by it.

Mr. G. P. Bidder,—Past-President,[1]—observed, that he differed very materially, in some respects, from the views advocated in the Paper; therefore any observations which he might make would be simply with a view of having the subject discussed solely with reference to its merits; but whatever difference of opinion there might be, to Mr. Bailey Denton was due the credit of having introduced a subject of great interest.

The members were indebted to Mr. Hawksley for the pains he had taken in bringing forward and criticising the enactments of an Act of Parliament which was passed last year. Mr. Bidder differed from those who thought it unnecessary that Engineers should study and discuss the laws of the country which affected their profession. He need hardly appeal to those members who were actively employed, to confirm his statement that, although they might be mainly engaged on mechanical points, yet fully one-half their time was occupied with questions political, legal, and social; and it was therefore incumbent on them to a certain extent to know the general bearings of the law, on questions of this importance. As to the Paper itself, he was bound to say, that he felt compelled to differ from the Author as to the accuracy of his facts, or that which should have made the facts important and useful. He would not now discuss the purely agricultural question, whether drains were better at the depths of 3 feet, 4 feet 6 inches, or 5 feet. Those were questions which would in time settle themselves, as each condition would have reference mainly to commercial considerations. The question of the depth at which water could be drained off, below 3 feet 6 inches, he believed to be wholly immaterial; therefore it was more a question of cost, which would depend on the nature of the soil, the inclination, and the locality. But with reference to the general question of draining land, particularly clay land, it was necessary to consider the importance of drainage, not only in an agricultural point of view, but also as it affected the rivers. Now the value of the Paper depended, as far as it went, upon the accuracy of the tabulated account of the observations. He had previously addressed a question to Mr. Bailey Denton with a view of ascertaining in what way the flow of water, had been tested, and he must confess that the impression made upon his mind was not very favourable, when he heard that the water was measured in buckets with chalk marks round the inside of them, especially as the results were very different from those which had come under his own observation.

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[1] Mr. Hawkshaw had been elected President before the conclusion of the discussion.

If the tables were correct, there had flowed from this land in the eight winter months more than two-thirds of the rainfall. Now this was so different from facts within his own knowledge, that he felt there must be some other fact withheld; when he said withheld, he trusted it would not for a moment be imagined that he implied that Mr. Denton had not communicated all he knew; but he thought there must be some fact which had escaped notice, and which it was most material should be ascertained. As far as Mr. Bidder's own knowledge and experience went, he knew no case, under any circumstances, in which two-thirds of the rainfall had ever been traced to flow from the land. It would be in the recollection of the members, that a very searching inquiry took place with reference to the drainage of the metropolis. An enormous number of experiments were made upon the rainfall and the flow of the sewers; and, to place the matter beyond dispute, some of the sewers of the metropolis were walled up, and every precaution was taken to confine the rainfall over a given area to distinct lines of sewers; and in dense parts of the metropolis, where the rain fell on slate roofs and paved back yards, almost every particle of water would find its way into the sewers; yet the whole of the experiments made by all parties, however antagonistic in other respects, coincided in this fact—that one-third of the rainfall, even in London, escaped observation, and never passed through the sewers at all, and in the suburbs the discrepancy was still greater. Such were the results in the metropolis, verified by observations of the most minute and extensive character. Now Mr. Bidder had observations accidentally coming within his own knowledge, which went far—he would not say to invalidate the results given in the Paper—but which showed, if they were correct, that some circumstances must have escaped Mr. Bailey Denton's observation. The land which Mr. Bidder possessed at Mitcham, lying on the south side of the Wandle, had been drained for some years. The drains were not so deep but that they would readily fill. In draining he allowed depths of 32 inches for grass land, and 36 inches for ploughed land; but from January until November, 1859, not a drop of water went off the land, through the drains, into the river; and from October to May—corresponding with the months in Mr. Bailey Denton's tables for 1856-7, but with 14 inches of rainfall as contrasted with 10 inches—not a drop of water went off the land through the drains; and it was not till the beginning of September, 1859, and November in the same year, with nearly 9 inches of rainfall, that any water came into the drains, and was discharged by them into the arterial channels of the country. This was so different a state of things to that quoted by Mr. Bailey Denton, that it would be most unwise to arrive at any conclusion on the subject, until observations were made of a much more extensive and universal character, over a more lengthened period of drought and rainy seasons, and upon greater varieties of soil, than any which had been hitherto brought forward.

With regard to evaporation, during the period he had referred to, as much as an inch of rain sometimes fell in an hour or two, and the ground absorbed it all; it would be erroneous to measure the evaporation by the difference between the rainfall of a district and that which ran off. The evaporative power of the soil could not be so measured. It depended upon a variety of circumstances. Before the evaporative power of the soil could be measured, the moisture must be supplied. Take the case of a turnpike road: in a hot season there was no evaporation; but if the road was watered two, or three times a day, it all evaporated; and if there was a large traffic, like that on a Derby-day, it would evaporate every two, or three hours. Therefore, in quoting the experiments of Mr. Charnock to show that the evaporation exceeded the rainfall, the evaporative power of the ground only was shown: and it would not be correct from that to assume the evaporative power in any year, that there should be 20 inches of rainfall with 16 inches of evaporative power.

It appeared to be agreed that, in dry seasons, there would be less water passing into the sewers, when the land was undrained, than when it was drained—he alluded to clay lands. The question limited itself, therefore, to wet seasons. With regard to that, it was necessary to see whether all the circumstances were stated, in order to ascertain the amount of the overflow from the land into the rivers. In lowering a lake 2 feet, or 3 feet, there would be the same flow from the lower level as at the higher level. In land the level of the water in the soil was only lowered. To what extent would the evaporation be influenced? because evaporation was the only other element which would disturb the quantity going into the rivers. The whole rainfall passed either by gravity into the rivers, or into the clouds by means of evaporation. There were many questions which affected this. In clay lands which were not drained, particularly grass land, the surface became what was termed 'baked,' and from a surface in that condition there was not any evaporation. On the other hand, the same field when under-drained would never become so baked, and evaporation percolated through the ground by means of the under-draining. He would also allude to a case where 9 inches of rain fell, in September, October, and

November, before the land became saturated, and that was nearly half the average rainfall of the county of Surrey. If that were so, the impression on his mind was, that unless in exceptional seasons like that of 1860, where there would be 6 inches of rainfall in June, as contrasted with no rainfall in 1859—taking the average evaporative power of the soil of the kingdom—even in winter seasons, the quantity of water which would be found, after all the evaporative power of the soil, would be less in land that was drained than in land which was undrained. He did not wish to dogmatise on that point; but he was of opinion that, before legislative action could be taken, more extensive investigations should be instituted than had hitherto been made, to settle a question of that importance; because, as Mr. Hawksley said, it was a question which affected not only the mill-power of the country, but also the chemical condition of our rivers; for, although when the rivers were well filled they would admit of a certain amount of pollution, yet if they were, as was the case in 1859, seriously reduced in the amount of their flow, that pollution, which in ordinary seasons might pass away without deleterious effects, must become poisonous.

He made these observations, not with the view of pretending that the opinions he had advanced were deserving of particular notice, but to point out the fact, that at present the data possessed, as regarded evaporation, and the evaporative power of the soil under all conditions, were insufficient to determine the question with satisfaction to the Institution, or to the public.

Mr. J. H. **Lloyd** stated that he was a director of a Lands Improvement Company, and in that capacity had turned his attention to the effects of under-drainage, not only in its agricultural aspects, but also as respected the arterial channels of the country. He did not think it possible to overrate the importance of this question, and he hoped that the Members of the Institution would by no means think it unworthy of their serious consideration. Sooner, or later it must force itself upon the attention of scientific bodies. It was quite idle now to suppose that the operations of drainage could be arrested. The beneficial effects had been so sensibly felt, so universally acknowledged, that even the stolid farmer of England—long waiting to be convinced—had found and admitted, that it was his interest to have his land well and thoroughly drained; and it was a fact within his own knowledge, as it would be within that of Mr. Bailey Denton, that whereas agricultural tenants were formerly opposed to drainage, and denied its beneficial effects, they now exacted as a condition from the landlord that it should be carried into effect, offering at the same time to pay an additional rent equivalent to, or even greater, than the annual charge created for the improvement. It was therefore impossible to suppose that the process could be stayed. Drainage would go on, wherever it was required; and whilst there still remained so much land to which it could be beneficially applied, the operations might be expected to be practically without limit. The Society of which he was a Director was, alone, expending at the rate of £300,000 a year in improvements of land, a great portion of which consisted of drainage; and other Companies were, he believed, in full activity.

It would be beside the question immediately before the Institution to go into any elaborate consideration of the mode by which the beneficial results of drainage were brought about. It might now be taken as an ascertained fact, that the effects, as well in agricultural production, as in an improved sanitary condition of the atmosphere, were most beneficial; and that, whatever the indirect effects in other ways might be, drainage must and would be continued. Taking that as a fact, then came the important consideration —were the operations, in doing such great good agriculturally, producing mischief in any other respects?—were they, by letting off the water previously lying, not only idly, but mischievously in the land—were they, in so doing, working injury in other ways, and if so, what remedies existed, and how and to what extent could they be applied for abating, or mitigating that injury? And here came in the province of the Engineer, because he it was who was to consider, and to help others in considering, the best way of effecting this object, with the least amount of detriment, or inconvenience, and with as little of arbitrary interference with the rights of others as the circumstances permitted. That was the problem to be solved, and it was with reference to that problem that the present discussion had been invited.

Mr. Bailey Denton had endeavoured, by a series of experiments upon a limited area (as must necessarily be the case when experiments were individually conducted), to ascertain the true effect of under-drainage in increasing, or in diminishing the supply of water in the streams and arterial channels. And although it might be conceded to Mr. Bidder, that the experiments were not by any means conclusive, and that being conducted on so limited a scale, and under such special conditions, they were perhaps insufficient to afford data from which any general conclusions could be drawn, yet it could not be denied that the Paper was a valuable contribution to the knowledge of the subject, and it established some important facts. He could not, however, give an entire assent to the deductions sought to be established from those experiments. His own observations and inquiries led him to the conclusion, that the apparent effect (for he spoke guardedly) of under-drainage, so far as it could be traced, was this: that although the quantity of flow into the rivers was not sensibly affected, yet the regularity of the supply had been materially disturbed. He believed the fact to be, that the quantity of water discharged into the arterial conduits of the country had, in wet seasons and during the period of floods, been augmented, and that in dry seasons it had been diminished. Whether that was a fact immediately and solely attributable to drainage was questionable; but of the fact itself there could, he thought, be no reasonable doubt.

In the case of the Trent, the Derwent, and other rivers of like character, he had heard that the owners of mills on those streams, who were the persons most directly interested in this question, and had better means of ascertaining the facts than others, alleged that the quantity of water in flood seasons was liable to large and sudden increase, whilst the normal flow in dry seasons was rendered still more scanty than before. Rightly, or wrongly, they attributed the consequence to the drainage operations; and the fact, if true, was most important, also, to owners of land in the valleys. If it was true, as he believed it to be, that the flood-line in the valleys had risen to a higher level, whilst the perennial supply of the springs in dry seasons had been diminished, it was a fact to which attention must be directed; and he thought that, reasoning *à priori*, there were sufficient grounds for supposing that the fact would be so. Nature, left to herself, had provided, that the water which was carried down from the higher grounds stored itself in various ways, partly by passing into underground reservoirs, from whence it issued in the form of springs, and partly by forming pools on the surface, or saturating low-lying hollows, from whence it passed off gradually by overflow; and thus a regular and tolerably average supply was secured through the whole year. But by under-draining, and thereby forming artificial conduits for carrying off the water, these sources were tapped, and the store of water held in the ground was carried off more rapidly. Indeed, to effect this was the very object of drainage, the principle being, that water held in saturation in the land interfered with the productive energy of the soil, and rotted vegetation at its roots. It was to relieve the soil from this excess, and to form a cellular mould, through which the air and water could pass freely, that drainage was undertaken.

If this assumption was erroneous, the whole system of drainage was wrong, and they were doing no good. It must be taken therefore as a fact, established by *à priori* reasoning, as well as by actual observation, that the water passed off more rapidly, and consequently that at the time of the greatest rainfall, when the natural flow would be greatest, they helped that flow, which was augmented by means of the artificial channels provided by drainage, and thus that greater floods were occasioned than had previously occurred. The effect of this upon the mills situated on rivers was very serious. Alluding only to a single instance—in the well-known Belper Mills on the Derwent, an addition of 150 H. P. of steam was found to be necessary to the water power which had previously been sufficient. To the mill-owner regularity of supply was as important as abundance. The fact was, that by the process of drainage immense good was done, by increasing the productive capabilities of the soil, to an extent inconceivable by those who were unacquainted with the ascertained results, and by improving the sanitary condition of the district, by carrying off the miasmatic vapours which were more, or less generated in all undrained localities. But having done that good in one direction, they must nevertheless provide against the mischief which might be created in another direction.

He would not pretend to analyse Mr. Bailey Denton's tables of rainfall and discharge; but he would remark, that there were not only the ordinary physical conditions, but also meteorological facts to be taken into consideration, before they could ascertain correctly the actual proportion between the rainfall and the outflow; but assuming the fact to be as had been stated, then came the practical question, what was to be done? It had been truly said, that this was a matter of national importance, which must force itself sooner, or later upon the attention of all persons interested in these beneficial processes. If the effect was to flood the lands in the valleys, and to stop the mills, it became necessary to consider in what way that mischief could be remedied. Accordingly, a body of gentlemen interested in agricultural improvement had formed themselves into a sort of association, for ascertaining the facts and applying the proper remedy. That body had in the last session of Parliament brought the matter under the notice of the legislature, which resulted in the passing of an Act, to which attention had already been drawn. Mr. Lloyd was aware that he was trenching upon legal matters, but he was speaking with reference to the general interests of the public, and not of the merits of this particular Act of Parliament. He did not purpose to deal with the subject, however interesting, or important in itself; but he might be permitted to say, it was a matter of engineering science, falling peculiarly within the province of the Institution to consider whether, and if so, in what manner, an evil of this kind, viz., the sudden accumulation of water in the valleys, producing floods at one time, and its undue abstraction producing drought at another season—could be remedied by the application of engineering skill and science. All questions of arterial drainage belonged to the province of the Engineer. And there was the still larger question, which had scarcely been adverted to, that even when the water had been got rid of locally; the mischief would not have been entirely cured, for it would then have to be considered, what provision was to be made for the final outflow of the surplus water.

The Act of last Session was, in that respect, imperfect. It provided only for the drainage of limited districts; and the problem still remained, how the water was to find its ultimate escape into the sea? That was, surely, an engineering matter; and until it was successfully accomplished, the evil would only have been transferred from one locality to another. They were in a constant struggle, as it were, with Nature. Bars were always forming at the mouths of rivers, and estuaries filling up; and unless a remedy were provided those evils would go on augmenting. It was not for him to suggest what the remedy should be; he only desired to urge the importance of some combined action, to consider and advise what was best to be done, and to suggest whether some general and comprehensive scheme could not be devised, probably with the co-operation of the Government (for the question, as he had said, was a national one), for arterial drainage. It was a subject than which none could more worthily occupy the attention of a scientific body like that which he had the honour of addressing.

Mr. MALLET would not have offered any remarks on this subject, but that he had had an opportunity of becoming acquainted with what had been done in arterial drainage in Ireland, where such operations had been more extensive than in any other portion of the United Kingdom. He agreed with Mr. Bidder, that the experiments now in question rested on too narrow a basis to be trusted as the certain support of the large conclusions that had been drawn from them; but during the discussion he had not heard any allusion made to very valuable information already before the public, deduced from the great arterial operations which had been executed in Ireland, and of which some portion might be found in the Transactions of the Institution of Civil Engineers of Ireland. Three important Papers had been read on this subject by Engineers who were engaged in the main drainage operations under the control of Mr. Wm. F. Mulvany, C. E., the Commissioner of Drainage, and a member of the Board of Public Works in Ireland. The last of those Papers, by Mr. Betagh, was, he thought, the most important communication on the subject that had appeared. It was, however, to be remarked that all these Papers were deficient in one most important element, namely, none of them gave the mean slopes of the catchments, from which the deductions as to proportion of rainfall and discharge were based, and without which all such deductions were of little general value. Mr. Mulvany, the Drainage Commissioner, was so fully impressed with the importance of this fact, that ten years ago he prepared a set of tables, to be filled up by observations made by his district engineers. Those tables had been filled up for an immense extent of country in Ireland, and no doubt they still existed in the archives of the Board of Works in Ireland, although they had not as yet been published. They contained a mass of information of a very valuable character, which it might be worthy the attention of the Council of the Institution to endeavour to have made accessible generally.

In the first Paper he had alluded to it appeared, that in certain catchments in the county of Mayo during ten months, the discharge of water was more than the rainfall during the same period—that actually more water came off the land than had fallen upon it, which at first sight might appear to involve a serious error; but no doubt the land was previously more than saturated, and was like a vast sponge giving out water slowly. On the river Glyde, passing the town of Ardee, before the main channels were opened by arterial drainage, it took a fortnight, or three weeks before a rainfall of storm water producing flood came down a distance of about twenty miles. That river meandered, like some parts of the Trent and the Ouse, over a vast tract of rich meadow land, encumbered with vegetation and bulrushes, which slowly let down the water. After the main channels were opened, the flood water came down the same distance within forty-eight hours.

As regarded the proportion between rainfall and discharge, he did not think that evaporation came much in question, unless the main arterial channels were thus seriously obstructed; if they were as free as they ought to be, there was not time for evaporation to come into play, so as materially to affect the result. More than 300,000 acres of land in Ireland had been brought under arterial drainage operations and had been thus improved; and it was the opinion of the best meteorologists in Ireland that these operations had already exercised a sensibly beneficial effect on the climate of that country. Ireland was to England the great sponge, as it were, for the absorption of the precipitated evaporation of the Atlantic waters; and it was not inconceivable that if the climate of Ireland was improved by the precipitated waters being thus more rapidly carried off, the effect ultimately might be that less rain would fall in England, and the climate of the latter might in some portions, especially along its eastern shores, become too dry.

The mean declivity of the surface of any large catchment was one most important element in determining the size of the channels for carrying off the arterial waters. The section of every stream in the world was a curve of the parabolic, or perhaps logarithmic order. Such was the section of the great historic rivers, as the Nile and the Ganges, the influence of which on climate and agriculture had engaged the attention of the oldest peoples in the world, and even moulded their theologies, or superstitions. The section always presented a hollow curve, rapidly increasing in eccentricity as it rose into the higher regions towards the sources; and the same sort of section applied to the smallest brook. The result of inquiries in Ireland was to show, that the rate at which the water ran off per acre per minute was greater in the smaller catchments than in the larger. The explanation of this fact, which he was not aware had before been given, was this, that small catchments were those of the greatest mean declivity of surface, and so they delivered off fastest. One of the most important collections of data, as to proportion of rainfall and discharge that existed, was to be found in the Blue Book of the Lords' Committee on Irish Arterial Drainage, of 1852. In that Report a Table was given of the rainfall and discharge for nearly forty large districts, some having a catchment of more than half a million of acres, others a very small one; but it was to be regretted that the average declivity was not given for any one of them. That element might still, however, be supplied, for those who had read the investigations of Humboldt, for determining the mean elevation of continents above the ocean, would see that the hypsometrical method employed by him for that purpose was capable of being applied also to this, and, aided by the Ordnance maps, it was possible to obtain the mean slope for any given catchment.

Mr. ROGERS FIELD said, one important point seemed to have been quite lost sight of, the fundamental difference between free soils and clay soils. Most of the observations which had been made applied only to clay soils, which were drained by close parallel drainage, and not to free soils drained by wide 'occasional' drainage. The wetness of clay soils proceeded only from the rain which fell upon the surface of the land, and consequently on them there could not be a greater amount of evaporation than rainfall. In free soils the case was different. There was then not only the wetness caused by the rain which fell immediately on the surface of the land, but that which was caused by the 'water of pressure' from adjoining higher lands percolating to the lower lands, and keeping them in a constant state of saturation. Mr. Bidder had said, that Mr. Charnock's experiments only showed the evaporative power of the atmosphere, not the actual amount of evaporation from the soil, as there would often be no water in the soil to be evaporated. This might be true as regarded clay soils, but it was certainly not true as regarded constantly-saturated free soils. In the latter case the atmosphere could fully exercise its evaporative power, as the water percolating from the higher lands would constantly supply the place of that removed by evaporation. To follow up the illustration, he might say that saturated free soils were in a similar condition to a road kept constantly wet by the leakage of a water-main beneath its surface, in which case evaporation would evidently have full play, though the surface of the road might never be watered. Therefore he contended, that in the case of saturated free soils, Mr. Charnock's experiments were strictly applicable. Those experiments showed, that the evaporation from soil maintained in saturation was 33 inches per annum, whereas that from drained land was only 20 inches; making a difference of 13 inches of evaporation saved by drainage. If there was any truth at all in these figures, the increase of supply to rivers from the drainage of constantly-saturated free soils must be very considerable. The next question was, did free soils exist to any large extent in this continuous state of saturation? There was no drainage where he had been engaged, in which there was not some land of this description. He would give an instance on a small scale that had lately come under his own observation. On an estate near Chester, which the General Land Drainage and Improvement Company were draining, there was a small field of 6 or 8 acres, consisting for the most part of clay, the outlet of which had run continuously during summer and winter. Before this field was drained, there was a large boggy spot in the middle of it, which was constantly wet, but with no surface overflow. On draining the field, it was found that the part consisted of porous soil, through which water was continually oozing from below. When the drains were cut the water went into them, and was discharged at the outlet, instead of rising to the surface and being dispersed by evaporation, and the result was a continuous flow from the outlet during summer and winter. The effect of the drainage there was, therefore, clearly to rescue water from evaporation, and thereby to create a perennial spring; and similar cases were of constant occurrence on all low lands.

Again, as regarded the effects of drainage upon floods, free soils differed very considerably from clays. Floods were caused by heavy falls of rain being rapidly discharged into the rivers. Now, on land in its natural condition this discharge was not so rapid when the rain had to percolate through the soil, before reaching the rivers, as when it flowed directly into them over the surface of the ground: this was shown by the fact, that rivers which derived their supply to a large extent from water of percolation, or springs, were not so much subject to floods, as those which derived their supply from surface overflow. Thus, for example, rivers in chalk districts which were largely fed by springs, were more uniform in their flow than those in clay districts. This had been strikingly shown by Mr. Homersham, in his comparison of the waterways of bridges with drainage grounds of the London clay formation and the chalk formation respectively. His measurements of eighteen different bridges showed that, for equal drainage areas, the waterway in clay districts was from three to ten times that in chalk districts, and moreover, that the bridges in the former districts were often filled with flood water, whilst those in the latter were very rarely if ever filled. On the other hand, the summer flow of rivers in chalk districts was considerably greater in proportion to the drainage area than that of rivers in clay districts.[1]

Now, the effect of the occasional drainage of wet free soils was clearly to reduce irregular surface overflow, and to substitute a more uniform discharge by percolation, as in chalk districts, and, consequently, its tendency must be to diminish floods, and to render the flow of the rivers more regular. The drainage of clays also tended to reduce surface overflow; but in them, partly on account of the large number of drains required, the discharge substituted was much more rapid and irregular than in free soils drained by a few skilfully-placed drains. Thus in clays heavy rains were immediately followed by a greatly increased flow from the drains. In free soils, on the contrary, sudden downfalls of rain did not much increase the flow. The water simply rose in the ground, which thus became, as it were, a reservoir, storing sudden downfalls of rain, and afterwards allowing them to be discharged gradually.

The Hinxworth experiments showed this equalizing action of the free soils very clearly. At the beginning of October the depth of the water beneath the surface of the land, as shown by the test holes, was 5 feet 4 inches. The water level then gradually rose, in consequence of frequent rains, and on December 12th it was 4 feet 1 inch from the surface. On December 13th there was a fall of nearly half an inch of rain, which raised the water to within 2 feet 11 inches of the surface. This constant rising of the water level showed that hitherto water was being stored in the soil. After this, however, there was hardly any rain for the rest of the month, the water level began to fall, and the soil to discharge what had been stored in it; and the consequence was, that in December there was more water discharged from the outlet No. 7 than the rainfall. Then the water began to rise again in consequence of more rain, and on January 12th it reached its maximum height, only 1 foot 11 inches from the surface. After this the water level gradually fell, with the exception of a few slight fluctuations, and at the end of February it was 4 feet 4 inches beneath the surface, or 2 feet 5 inches lower than on January 12th. A large quantity of the water that had been stored was thus set free, causing such an increase of flow, that, whereas the rainfall during February was only 4,343 gallons per acre, the discharge from outlet No. 7 was 27,360 gallons, or more than six times the rainfall.

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[1] *Vide* Beardmore's Hydraulic Tables, p. 31.

He, therefore, thought it was evident, that free soils, when properly drained by a few occasional drains, would tend to equalize the discharge of the rainfall, and consequently to make the flow of the rivers more regular.

Mr. JAMES BRUNLEES was of opinion, that draining was not generally so well understood as it ought to be, considering that sound views of it were entertained more than two centuries ago. In 1652, in a treatise on draining by Captain Walter Blithe, it was said, "superfluous and venomous water, which lyeth in the earth and much occasioneth bogginesse, mirinesse, rushes, flags, and other filth, is indeed the chief cause of barenesse in any land of this nature * * * Draining is an excellent and chiefest means for their inducement; and for the depth of such draynes, I cannot possibly bound, because I have not time and opportunity to take in all circumstances," * * * and again, "yea, suppose this corruption that feeds and nourisheth the rush, or flag should lie a yard, or four feet deep, to the bottome of it thou must goe, if ever thou wilt drain it to purpose. To the bottome where the spewing spring lyeth thou must goe, and one spade's depth, or graft beneath, how deep soever it be, if thou wilt drain thy land to purpose. I am forced to use repetitions of some things, because of the suitablenesse of the things to which they are applied; as also because of the slownesse of people's apprehension of them, as appears by the non-practice of them, the which wherever you see draining and trenching you shall rarely find few or none of them wrought to the bottome." These were the common-sense views of draining two centuries ago, and were they acted upon now, each kind of soil would be drained in such a way and at such a depth as would meet its peculiar requirements, and ineffective drainage would be unknown. It had been stated that in the fens, more especially in peaty soils, a depth of 30 inches was found to afford sufficient drainage. To show that this statement was incorrect, he would draw attention to the fact, that in fen lands where the material had been thrown into mounds alongside the ditches, there was found in these mounds the most luxuriant vegetation, and the cause of this was evidently that the roots of the plants were farther removed from the cold sour soil.

It was true that there had been instances of peaty and fen lands having suffered during parching and protracted dry weather, in consequence of their being so loose that capillary attraction failed to raise the water to the roots of the plants; but, even though this might occasionally be so, he would still say with Blithe, drain deep enough to prevent the land from being soured by stagnant water in wet seasons, and for droughts let the ditches be provided with dams, or sluices to raise the water at pleasure to any required height. The general depth of drain recommended by the late James Smith, of Deanston, was 2 feet 6 inches, but many of his drains had, since his death, been reopened and replaced at depths approaching 4 feet. One member had stated that he had put drains in his land at depths varying from 32 inches to 36 inches, but that little, or no water came from them. The reason was obvious,—like Smith of Deanston, he had put the drains above the level of the water-bearing strata, and hence it was not till after a very heavy fall of rain, when the level of the water was raised in the strata up to the pipes, that they began to discharge.

Part of Mr. Brunlees' early life had been spent in the midst of drainage operations, and he had always been a close observer of the effect on vegetation. He had invariably found, that it mattered not whether at home, on the continent, or under a tropical sun, to secure vegetation there must be either natural, or artificial drainage; but to have vegetation in perfection, there must be deep and ample drainage. He need hardly add, that he fully agreed with Mr. Bailey Denton in recommending draining at 4 feet to 8 feet in depth, for in the porous soils it was essential to be under the soaks and springs, and in the clay and tenacious lands, 4 feet, 8 feet, or more, would not be found too much. Every one accustomed to making, or maintaining railway cuttings in this heavy class of soils must have noticed that, from a small soak, or spring, capillary attraction gradually extended the moisture until it caused a large slip. The same operation went on in underground drainage; the water was diffused by capillary attraction to feed the roots of the plants, and hence the level of the stagnant water would be practically too low.

The outfalls of rivers were differently affected by draining. He had no doubt of the correctness of what was said in reference to the river Thames remaining longer in flood at present than it did when the lands were but partially drained; for, where the lands had been thoroughly drained and became saturated by continuous rain, the drains would pass off the water more freely, and thus augment the volume of the river. The same effect would be produced in every river having a low rate of fall, like the Thames; it was, therefore, only in rivers of that class that attention to the outfall was required. Taking, as an opposite instance, the river Tweed, which had a rapid fall, and passed through a district which in general had been thoroughly drained, the floods were not anything like so high as they were twenty-five to thirty years ago, but they both rose and fell more rapidly than they did formerly. There were two important features noticeable in that river; the first was that since the general introduction of drainage, from the water having to percolate into the drains, the surface soil was not washed away from the land into the river; and, second, and consequent on the first, the river, during floods, was now less charged with mud, and hence there was less deposit carried to the river's mouth to form bars and impediments to the shipping.

Mr. Bailey Denton, in replying upon the discussion, said, he did not feel surprised that a Paper which had cost him so much consideration, and he might say twenty years' collection of facts to support its conclusions, should have received so little attention to its details as this had done. He did not say that in the way of reproof, or regret. It was quite impossible that members could collect all the details therein set forth. He did, however, feel astonished at some of the observations which had fallen from Mr. Bidder. That gentleman, when President of the Institution, had asked him to present a Paper, which should contain the results, not of a single experiment, but of his experience of drainage for years; and when he found Mr. Bidder, with a manner so potent, expressing an opinion that the mode of measuring was doubtful, he could not resist the assertion that, having paid much attention to the single object of drainage, and having made it his business, for some years past, to collect results founded on the most perfect and accurate observations, conducted in various ways, and involving different modes of measurement, he knew no more simple and accurate mode of measuring the discharge of water from drains, of the size and character here referred to, than the method adopted and already explained. He might quote the evidence of Mr. Clutterbuck, who having witnessed these experiments, had written,—"I was more than once on the spot, and, in many instances, insisted upon the outfalls being re-gauged in my presence, in order to verify results for which I was not prepared." He thought there could be no reasonable doubts as to the accuracy of these measurements.

It was to be remarked, that the Hinxworth experiments were not given as exhibiting the quantitive discharge from all drained lands; for in various localities, there would be different quantities of rainfall and discharge. He had never offered them as exemplifying more than the relative action of, and discharge from, the two characteristic soils,—the clays and the free soils. He had experiments now going on in fourteen, or fifteen different places in England, all giving different quantities to these, though consistent with them in the relative deductions to be drawn from the draining of the two species of soil. His Paper, at any rate, had satisfied one particular point, and that was the necessity of attending to the question of "arterial" in relation to "under" drainage, which for the present was all he aimed at. Every one had concurred in the statement, that, at certain periods, the discharge from the upland drainage already affected, and would continue more and more to affect the rivers.

Some observations had been made on the extent of the area upon which these experiments had been carried on. Mr. Bidder had referred to some experiments of his own, but he had not given the details in that tangible way that would enable a comparison to be made with the statements in the Paper. In fact, Mr. Bidder had stated, if he understood rightly, that the under-drainage at Mitcham discharged no water at all. The experiments before the Institution, small as they might be, had extended over 100 acres, which he believed was the largest area ever experimented upon. Now, most of the experiments, to which reference had been made, were restricted to superficial areas of ten and twelve inches square. Mr. Dickenson's experiments were made on twelve square inches of surface; Dr. Dalton's were on ten inches, and Mr. Charnock's on twelve inches square. He did not mean to imply that they were inaccurate, because they were confined in extent. He had more respect for multiplicity than breadth of experiments. Liebig had said, "Science could never be wrong;" and it was by the repetition of experiments that facts could be ascertained and science founded.

He had three objects in bringing forward this Paper. The first was to obey Mr. Bidder's presidential request; the second was to show the Institution that there was an object unattended to, which ought to receive their attention, and which, as Mr. Lloyd had truly said, must come sooner, or later upon the country, and force itself upon the attention of Engineers. If he wanted any eulogium on his efforts in the matter, it would be found in the remarks of Mr. Hawksley, who, in his eagerness to protect the miller, had shown that almost every Engineer would be called into requisition to defend water rights. In the third plan he was personally anxious, that the engineering view of under-drainage should receive the attention of the Institution, although, perhaps, an object foreign to many of its members. Millions were being expended in perfect ignorance of true science, and with a total disregard of those principles which Engineers would recognise. The mere 'gridiron' of drains, represented by the lines on a map of a clay soil, to which they were applicable and appropriate, was not science. Anybody could rule parallel lines on paper and set them out on land; but if they turned to the wet free soils, the extent of which in Great Britain was within a trifle equal to that of the clays, it would be found that in that case science was really required. They had not in such soils to multiply drains to overcome excessive retentiveness; but they had to reduce the water level through percolative matter and to let off, carefully and gradually, that rain which fell upon the surface, and that water which gravitated through adjacent land into such soils; not to extract it too freely, but to remove the evil of stagnation, and to discharge the water into the rivers, with as little disturbance to the arterial system as possible; not to 'gridiron' each field as a separate work, but to regard each valley, or area of saturated free soil, as subject to a system of drainage, capable of both overcoming stagnation and of increasing the perennial water supply. It was not possible to remove surplus water from clays too quickly, but it was quite possible to remove it too rapidly from free soils; in fact, the more gradual the action of drainage, so long as the water was kept moving, the better for that species of land, and the less derangement of the arterial system would be the consequence. This was a point which must some day receive attention from the Engineers of Great Britain, and have its due influence in the mode of under-draining itself. He said this from a conviction, that the absence of such reflections was hurrying the country into a state of confusion, becoming worse confounded every day; and it would explain, too, the over-draining of certain meadow land, of which so much was said. It was hardly to be expected otherwise, when it was remembered that, from a sense of economy, the landed interest generally left the control of drainage works on their estates in the hands of bailiffs and superior farm-labourers, and dignified the operations by calling them "Government drainage on scientific principles." It seemed almost ridiculous, when science was so deservedly paramount, that in land drainage, an art essentially dependent on engineering and geological data, a parallel ruler should be the guide in all soils and all surfaces. He must refrain from replying seriatim to the observations of the several speakers, although he could say a great deal upon each; but there were a few words which fell from Mr. Gibbs which called for special remark. That gentleman had said that, if they drained too deep, capillary attraction was weakened; and, if too shallow, the air would not penetrate. He begged to join issue. If under-draining was adequately deep, it reduced evaporation, by lowering the water-bed beyond its direct influence, and he had observed that capillary action, when it was uninfluenced by evaporation, was greater, the deeper the under-drains were placed in the ground, arising from the fact that the interstitial spaces were smaller. If a soil constantly moistened by subwater, by capillary action, or otherwise, was subject to full evaporation, it was chilled, and the nearer a soil approached a state of saturation, and the nearer the water-bed to the surface, the more it evaporated and the colder it was. The amount of moisture, too, seized by the soil, permeated by the atmosphere, was necessarily greater in proportion to the depth of soil penetrated.

Some remarks had been made as to the necessary depth of drainage. That was truly an agricultural detail, and he so recognised it; but, if time permitted, he could show that it was also an engineering question, particularly in dealing with free soils saturated by rain and lateral pressure. Reference had been made to maintaining the water level in peat lands, at from 2 feet to 2 feet 6 inches, as being necessary for the maintenance of the peat in a state of fertility. He could assure the Institution that his experience was directly opposed to that statement. Peat land was consolidated and its fertility was enhanced by deep under-draining. He had been consulted in Holland with a view of introducing under-drainage there, and he might add, that under-drainage in the Fens, 4 and 5 feet deep, was extending every day. Referring the Institution to the quotation from Judge French which he had given in the Paper, he was willing to leave the matter there. But he might be allowed to quote an observation of Lord Palmerston on this subject which had made an impression upon him. When speaking to his Lordship on sub-irrigating peat lands,—*i. e.*, letting water into the land as Fen men did into their ditches,—his Lordship said, "You may do it if you like, but I do not think well of it. A good gardener of the present day never waters his plants from the saucer, as in olden time, but invariably from the surface of the pot, and discards the saucer." In the same way the drainer ought to keep the water level beyond the reach of active evaporation, and to look to aëration and capillary attraction to maintain, with occasional rain, the necessary moisture.

As there were two characteristic kinds of soil, the clay and the free soils, so there were two sorts of wetness,—the wetness from rainfall, and the wetness of saturation, maintained by pressure from surrounding land. So, also, there were two periods and characters of discharge, one, the intermittent, which got rid of the redundant rainfall which found its way from the drains in the clays; and the other, the constant, or perennial discharge, which resulted from under-draining the saturated free soils. The effect of draining the clays, as had been generally admitted, was to throw down into the valleys immense quantities of water, during the discharging period, which by the Hinxworth Tables was shown to last from October to April. This intermittent excess, which affected the rivers, was at the service of engineers, if it was properly stored and applied where wanted; and the observations of Sir John Rennie on this point agreed with those which Mr. Denton had written twenty years ago, in a Paper which was in the library of the Institution, and which dealt with the "application of drainage water!"[1] The effect of drying the saturated free soils of the country would be to improve,—that was to increase,—the perennial supply of water to the rivers, by withdrawing from the atmosphere that which the drains discharged in the summer months. He commended that point seriously to the attention of the members. His views were not at present generally concurred in, but he looked forward to a time when they would be so. Formerly he held the opinion expressed by Mr. Lloyd, that the effect of under-draining must be to increase the drought of summer; he now withdrew that opinion, on the simple grounds, which his observations and experience had confirmed, that as no water could be discharged from any drains, until the soil was filled up to the level of the drains, the subterranean supply could not be diminished, and that whatever water was rescued from the atmosphere was a gain to the rivers during the summer.

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[1] *Vide* "The Question what can now be done for British Agriculture? &c." By J. B. Denton. Tract 8vo. London, 1842.

He was now obliged to close his observations, and he left the subject in a way he did not like to leave it; he felt it had not yet been understood, and that few had followed the Paper throughout. Recurring to the disputed question, as to increasing the perennial supply, he held in his hand a letter from Lord Palmerston, written on the day on which the decision upon the American war was expected to be known in England. It was a letter of no less than six and a half pages; and it was a most interesting fact that his Lordship, at such a momentous time, should write a long letter of that sort, going as fully into the subject as any Engineer could do, and drawing very different deductions from those he had heard in the course of this discussion, and which were popular in the country:—

(Copy.)

"94 Piccadilly, *6th January*, 1862.

"My dear Sir,

"I have received your letter of to-day. The question to which it relates seems to me to be as clear and as simple as anything can be. It is demonstrable that under-draining must render more dry the atmosphere of the lands drained; and, it is equally plain, that it cannot materially, if at all, diminish the supply of water to any river that flows through such lands. Undrained land is like a sponge, it is saturated with the moisture which, by capillary attraction, it draws up from below, and, by the moisture which, in certain conditions, such as sea fogs, it imbibes from the atmosphere, and with the water which falls in the shape of rain or snow. The moisture thus held by this spongy upper stratum of the land, is got rid of mainly by evaporation into the atmosphere in contact with such land, and the quantity of water with which that atmosphere is then charged is, in some cases, very considerable, and, being much greater than the air can hold in solution, it is precipitated in the shape of mists and fogs to the detriment of the health of the inhabitants of the district. The effect of sufficient under-draining is to convert four or five or six feet of the upper crust of the land from the condition of a sponge to that of dry earth. That thickness of crust no longer draws moisture from below by capillary attraction,[1] and the water which falls upon it as rain or snow, or which is deposited upon it by sea fogs, instead of rising into the atmosphere by slow evaporation, finds its way rapidly into the drains, and is carried off by them. The soil will however, always, by its retentive nature, keep to itself moisture enough to supply the wants of vegetable roots. The good effects then of draining upon the atmosphere of the district drained are demonstrable in theory, and anybody who, like me, has had drained a large extent of land, which before had been very wet, will have amply experienced those good effects in practice. The improvement in the atmosphere of that part of the valley of the Test, which extends from a mile above Romsey to two miles or more below it, is most striking and satisfactory, and is entirely owing to the drainage works which have been executed within those limits. But, then, as to the effect of under-draining upon the supply of water to rivers. Rivers are supplied with water by rivulets which flow into them, and by water which rises from springs in their beds as they flow along. The rivulets will probably be increased in volume by draining works, because they will be made the outfalls for the drainage of land on higher elevations. Then, as to the water, which was before contained in the four or five upper feet of the land through which the river flows,—that water, instead of being evaporated into the atmosphere, is carried along the under-drain, and is delivered into the river at the earliest point at which the descending level of the river will give a sufficient outfall; and supposing the depth of the drain to be five or six feet, in a river of average rapidity of current, the drained water may be discharged into the river at no very great distance from the beginning of the system of drains. Then, as to the feeding springs which rise up in the beds of rivers, the only water that is withdrawn from them is that which would have been contained in the four or five feet of the upper surface of adjoining lands,—and I have already shown that, as regards such water, the river is a gainer and not a loser by the drainage. All the water in the soil below four or five feet from the upper surface of the land will as before find its way in springs to the beds of the rivers, without being in any way diverted from its course by the drainage of the upper surface. That this has been the case with the Test, I can assert by experience, for the volume of its water has not been in the slightest degree affected by the drainage works in adjoining lands. It has so happened that the river has been much fuller of water during the last two years than it had been for several years before; but that was owing to causes quite unconnected with the drainage works.

"My dear Sir,
"Yours faithfully,
(Signed) "PALMERSTON.

"*B. Denton, Esq.*"

This letter of Lord Palmerston's fully supported the opinions which Mr. Bailey Denton had set forth, and had pressed so earnestly on the Institution, viz., that, by draining the valley lands, that were in a continual state of saturation, an amount of water was saved from evaporation during summer, which must go to increase the perennial supply of the rivers.

Mr. Denton handed in the following tabular statement to be appended to his reply:—

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[1] This expression is subject to modification. See observations in reply to Mr. Gibbs, page 124.—J. B. D.

TABULAR STATEMENT of Experiments at Broadlands, showing the depth to which the water has been lowered by under-drainage, and the fluctuations in the water-level according to the rainfall.

	Depth of Water in Test Holes below surface of Ground.						Rainfall.		
1861.	Minimum Depth during Month.		Circumstances under which Minimum occurred.	Maximum Depth during Month.		Circumstances under which Maximum occurred.	Monthly Rainfall at Southampton.	Monthly Rainfall at Eling.	Number of Days in which Rain fell at Southampton.
	Ft.	In.		Ft.	In.		Inches.	Inches.	
Feb.	3	0	After 3 days' rain amounting to 0·55 in.	4	1	After 4 days' cessation of rain.	1·52	2·92	10
Mar.	3	5	After 0·55 in. of rain in 1 day.	4	3	After 3 days' cessation of rain.	1·83	2·25	11
Apr.	3	9	At beginning of the month.	4	4	After continued cessation of rain.	0·27	0·39	3
May	4	0	After 0·95 in. of rain in 1 day.	4	5	After continued cessation of rain.	1·39	1·56	4
June	3	7	After 1·000 in. of rain in 1 day.	4	5	At the beginning of the month.	3·29	3·94	13
July	3	7	After 0·87 in. of rain in 2 days.	4	1	After 5 days' cessation of rain.	3·19	4·59	14
Aug.	3	10	Little rain.	4	6	After continued cessation of rain.	0·60	0·60	4
Sept.	4	1	After 0·45 in. in 1 day, preceded by continuous rain.	4	8	After several days' cessation of rain.	3·02	3·15	13
Oct.	4	2	At beginning of the month.	4	7	At end of month never less than 4 ft. 5 in. for 26 days.	0·78	0·77	9
Nov.	3	5	After 1·60 in. of rain in 3 days.	4	7	At beginning of the month.	4·61	3·50	11
Dec.	3	11	After 0·44 in. in 2 days.	4	5	At end of the month.	1·16	2·02	8

The minimum quantity of water discharged by the under-drains during the above period of eleven months was about fifty gallons per minute, and the maximum quantity exceeded ninety gallons per minute, showing the large amount of evaporation there must have been before under-draining, and the saving effected in favour of the river and the mills below.

The drainage at Broadlands had been executed in 1860-1, in conformity with Mr. Denton's report on the Test Valley, 1853, in which the following remarks were made :—

> "As the saturated surface of the valley is constantly presented to the action of the sun and wind, and the peat soil is peculiarly susceptible of capillary action, the amount evaporated will be found to exceed on an average of years the proportion from the porous chalk by at least one-half. Whatever, therefore, is the difference between the evaporation from a constantly wet surface, compared with a drained surface, will represent the loss by evaporation to the miller for power and the irrigator for water, and which neither the one nor the other would perhaps imagine, in the valley of the Test, amounted to 750 tons per annum, from every contributing acre of land.
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> "But this is not the whole of the miller's loss by the present undrained condition of the valley. It is manifest that the proportion of the rainfall which usually filters through a *porous* soil, and gradually finds its way out again at a lower level, in the present state of the land flows over the saturated surface to the sea as soon as it falls when water is necessarily over abundant. This loss might be in a great measure saved by rendering the surface constantly open and absorbent by drainage, and qualifying it to yield up, for the use of the mills, water which would otherwise never find its way into the stream. It may be fairly assumed, that from these two sources of evaporation and overflow, twelve inches of water over the whole surface of the valley are lost in every year."

Mr. Hawkshaw,—President,—quite agreed with what had been stated with respect to the drainage of land, and its great importance to the prosperity and wealth of the country; so much so, that any information which was brought to bear on it by Civil Engineers and others who devoted their attention to it was of vast consequence to the country. He did not think it necessary to try to preserve the mills, or the mill power as a rule, in the expectation, or on the hypothesis that coal might become so dear, or so scarce as to render it probable that it would be obligatory, some day to return to what was called "water spinning." He thought that would be interfering with the progress of improvement. Wherever mill power was destroyed, of course it should be compensated for. He would not enter into a consideration of the provisions of the new Drainage Act, which had been so frequently referred to in the course of the discussion, because he thought it hardly came within their province as Engineers to do so. Nor had he any reason to doubt the accuracy of Mr. Bailey Denton's figures, as to the discharge of water from the drains, in the experiments which he had brought before the Institution. He had read the Paper, and had compared those results with what was probable, and he quite conceived he might obtain from land, under certain circumstances, and on such an area as he had operated upon, the quantity of water which he had stated. Of course whether the quantity of water, so discharged by those drains, represented the area of rainfall on the land, was another question. For anything that was known, the quantity of water so discharged might be from a much larger area of rainfall than that which belonged to the extent of land drained. In draining what were called free soils, into which the water came from more distant points, it was possible in 100 acres to get the rainfall of 300 or 400 acres. But Mr. Denton obtained about one-fourth of the rainfall. Some years ago, when it was proposed to sink a well at Watford, it was necessary to go into that question very carefully, and it was found, that under certain circumstances 27 per cent. of rainfall had passed through 3 feet of earth; therefore he did not make these observations with a view of leading to the supposition, that it was correct to take the results which had been given, as a basis on which to argue as to the régime of rivers.

With regard to the important question, to Engineers, as to the effect of land drainage on the régime of rivers, he concurred with many of the speakers, that a larger amount of information was requisite, before it would be safe to generalise on the subject. He must confess, that he had arrived at rather an opposite opinion to that which the Author would lead the meeting to form on that subject. He believed that on certain soils drainage might diminish the quantity of water which passed to the rivers; though he thought there were cases where it might have a contrary effect. But still he was not sure,—admitting what had been stated, and he thought the conclusions were perhaps sound as regarded the particular locality referred to—yet he imagined there were cases where the result might be quite different. For instance, chalk would absorb one-third of its bulk of water. When there were 30 inches of rainfall the chalk would absorb 10 inches. Then taking a soil which did not naturally resemble chalk, but which by draining might have the character of chalk given to it, by adding to its porosity and by draining it, then, instead of the water passing off quickly to the rivers, it would be absorbed, as in the chalk, and it would be given out again by evaporation. He mentioned this as a case where the results might be opposite to those which had been given.

Where drains were put into a free soil, the water was led away quickly instead of having time to saturate the surface; thus evaporation was diminished, and the water was taken away to the streams, and then an addition was made to the quantity of water coming into them. He thought therefore that much more information must be obtained before it would be possible to form sound conclusions on that point.

With regard to the question of drainage itself, he did not profess to have sufficient knowledge of it to be able to enter into the details of the depths necessary for the drains, whether they should be 3 feet, or 4 feet. That was a matter which could only be arrived at by practice and experience, and it depended very much on the nature of the locality operated on. He would say in conclusion, that the Institution was much indebted to Mr. Bailey Denton for the Paper, which contained much information, and would be useful to all who were interested in the subject.

December 10, 1861.

GEORGE PARKER BIDDER, President,
in the Chair.

Before proceeding with the regular business, the President directed attention to the numerous donations to the library, which had been received during the recess; particularly noticing the series of seven volumes of "Transactions of the North of England Institute of Mining Engineers," through the President of that Institute, Mr. N. Wood, M. Inst. C.E.; the volumes containing the abstracts of "The Principal Lines of Levelling in England and Wales" and in Ireland, from Colonel Sir Henry James, R.E., C.B. (Assoc. Inst. C.E.); "The Quarterly Review," vols. I. to LX., from Mr. J. S. Crossley, M. Inst. C.E.; thirty-five volumes of "Greenwich Observations" and other publications of the Royal Observatory, Greenwich, through Professor Airy, Hon. M. Inst. C.E.; the "Annales des Ponts et Chaussées" from 1843 onwards, through Monsieur Cavalier, Directeur de l'Ecole des Ponts et Chaussées; the "Journal of the Franklin Institute" from 1851 to the present time, from the Institute; a set of the Alphabetical, Chronological, and Subject-matter Indexes of Patents for Inventions, together with the Abridgments of Specifications relating to different subjects, from H. M. Commissioners of Patents, through Mr. Bennet Woodcroft; the series of volumes detailing the Magnetical and Meteorological Observations made at different stations in the British Colonies, through General Sabine, President of the Royal Society; the Publications of the Geological Survey of Great Britain, through Sir Roderick Murchison, Director-General; a Geological Chart of the Austrian Empire ("Geognostische Uibersichts Karte der Oesterreichischen Monarchie"), from Mr. J. R. McClean, Vice President; and a copy of the New Edition of "The Encyclopædia Britannica," from Mr. H. P. Stephenson, Assoc. Inst. C.E.

The President, in proposing that the special thanks of the meeting be given to the several donors, expressed the hope that these excellent examples would not be lost upon the many new Members and Associates who had recently joined the Institution, and that it would be the constant aim of the Members of all classes to maintain the library in the highest state of completeness.

The Discussion upon the Paper, No. 1,046, "On the Discharge from Under-drainage, &c." by Mr. Bailey Denton, was continued throughout the evening, to the exclusion of any other subject.

ANNUAL GENERAL MEETING.

December 17, 1861.

GEORGE PARKER BIDDER, President,
in the Chair.

MESSRS. ADAMS, STILEMAN, and WEBB, were requested to act as Scrutineers of the Ballot, for the election of the President, Vice-Presidents, and other Members and Associates of Council.

The list of the attendances of the Members of Council for the past year was read, and the Ballot was commenced; the balloting-papers being sent for examination, at intervals of fifteen minutes, in order to expedite the labours of the Scrutineers.

The Annual Report of the Council, on the proceedings of the Institution during the past year, was read.

Resolved,—That the Report of the Council be received and approved; and that it be referred to the Council, to be printed and circulated with the Minutes of Proceedings, in the usual manner.

Resolved,—That the thanks of the Institution are due, and are presented to Messrs. Kingsbury and Stileman, for the readiness with which they undertook the office of Auditors of Accounts, and for the clear statement they have laid before the Meeting; and that Messrs. Stileman and Bramwell be requested to undertake the office of Auditors for the ensuing year.

The Telford Medals, and the Council and Manby Premiums of Books, which had been awarded, were presented.

Resolved,—That the thanks of the Institution are justly due, and are presented to the Vice-Presidents and other Members of the Council, for their co-operation with the President, their constant attendance at the Meetings, and their zeal on behalf of the Institution.

Mr. Hawkshaw, Vice-President, returned thanks.

Resolved unanimously,—That the cordial thanks of the Meeting be given to Mr. G. P. Bidder, President, for his strenuous efforts in the interests of the Institution, for his extraordinary attention to the duties of his office, and for the urbanity he has at all times displayed in the Chair.

Mr. Bidder returned thanks.

Resolved unanimously,—That the cordial thanks of the Meeting be given to Mr. Charles Manby, the Honorary Secretary, and to Mr. James Forrest, the Secretary, for the ability they have shown in the execution of their duties, and for their constant attention to the interests of the Institution, and to the individual wishes of the Members.

Mr. Manby and Mr. Forrest returned thanks.

The Ballot having been open more than an hour, the Scrutineers, after examining the papers, announced that the following gentlemen were duly elected to fill the several offices in the Council for the ensuing year:—

President.

JOHN HAWKSHAW, F.R.S.

Vice-Presidents.

John E. Errington.
John Fowler.
Charles H. Gregory.
John R. M'Clean.

OTHER MEMBERS OF COUNCIL.

Members.

Sir W.G. Armstrong, C.B., F.R.S.
Joseph Cubitt.
Thomas E. Harrison.
Thomas Hawksley.
George W. Hemans.
John Murray.
John Scott Russell, F.R.S.
George Robert Stephenson.
Charles Vignoles, F.R.S.
Joseph Whitworth, F.R.S.

Associates.

John Cochrane.
Colonel Simmons, R.E., C.B.

Resolved,—That the thanks of the Meeting be given to Messrs. Adams, Stileman, and Webb, the Scrutineers, for the promptitude and efficiency with which they have performed the duties of their office, and that the ballot-papers be destroyed.

ANNUAL REPORT.

SESSION 1861-62.

THE proceedings of the Institution during the past twelve months, to which this Report is exclusively devoted, will contrast favourably with those of any previous year. The more than ordinary attendances at the meetings show, that the subjects brought forward for discussion have equalled, even if they have not exceeded, in interest those of former sessions. The elections of Members and Associates have been as numerous, and as a consequence the abstract of accounts will be found to exhibit a very satisfactory result. Considerable additions have been made to the library, to which the attention of a Special Committee of the Council has been closely directed.

In making the preliminary arrangements for the approaching International Exhibition of 1862, her Majesty's Commissioners asked the Council to nominate some gentlemen to serve as Members of a Central Committee, in connexion with Classes V., VII., VIII., and representing—

Class V.—Railway Plant, including Locomotive Engines and Carriages.
„ VII.—Manufacturing Machines and Tools.
„ VIII.—Machinery in general.
„ X.—Civil Engineering, Architectural and Building Contrivances.

Accordingly, the names of Mr. M'Clean, Vice-President, and of Messrs. Cubitt, Harrison, Hemans, Scott Russell, and Captain Galton, R.E., Members of Council, were submitted, and those gentlemen were subsequently appointed.

The principal Papers read during the past Session were:—"On the River Orwell and the Port of Ipswich," by G. Hurwood (M. Inst. C.E.); "On the Maintenance and Durability of Submarine Cables in Shallow Waters," by W. H. Preece (Assoc. Inst. C.E.); "On the Rise and Fall of the River Wandle; its Springs, Tributaries, and Pollution," by F. Braithwaite (M. Inst. C.E.); "On the results of trials of varieties of Iron Permanent

Way," by F. Fox (M. Inst. C.E.); "Description of the Pier at Southport, Lancashire," by H. Hooper (Assoc. Inst. C.E.); "On the Construction of Floating Beacons," by B. B. Stoney, B.A. (Assoc. Inst. C.E.); "On the North Sea; with remarks on some of its Friths and Estuaries," by J. Murray (M. Inst. C.E.); "On the Floating Railways across the Forth and Tay Ferries, in connexion with the Edinburgh, Perth, and Dundee Railway," by W. Hall (Assoc. Inst. C.E.); and "The National Defences," by G. P. Bidder, junior, M.A. (Assoc. Inst. C.E.)

The following Telford Medals, and Council and Manby Premiums of Books, have been awarded to the Authors of some of these communications:—

1. A Telford Medal, and a Council Premium of Books, to William Henry Preece, Assoc. Inst. C.E., for his Paper "On the Maintenance and Durability of Submarine Cables in Shallow Waters."
2. A Telford Medal, and the Manby Premium, in Books, to George Parker Bidder, junior, M.A., Assoc. Inst. C.E., for his Paper on "The National Defences."
3. A Telford Medal, to Francis Fox, M. Inst. C.E., for his Paper "On the Results of Trials of Varieties of Iron Permanent Way."
4. A Council Premium of Books, to Frederick Braithwaite, M. Inst. C.E., for his Paper "On the Rise and Fall of the River Wandle; its Springs, Tributaries, and Pollution."
5. A Council Premium of Books, to George Hurwood, M. Inst. C.E., for his Paper "On the River Orwell and the Port of Ipswich."
6. A Council Premium of Books, to William Hall, Assoc. Inst. C.E., for his Paper "On the Floating Railways across the Forth and Tay Ferries, in connexion with the Edinburgh, Perth, and Dundee Railway."

Mr. Murray's Paper, on "The North Sea," was not taken into consideration by the Premium Committee, in accordance with the custom, that communications from Members of Council should not be eligible for Premiums. It is, however, felt that the special thanks of the Institution are eminently due to Mr. Murray for the interesting Paper now referred to, which ranks well with many others previously contributed by him.

At the first meeting, the discussion was renewed upon Mr. Michael Scott's Paper "On Breakwaters, Part II.," which had been read during the previous Session. The discussion seemed to resolve itself into two separate questions, the best form of wall, in a theoretical point of view, to resist a deep-sea wave, and the cost of securing that form. With regard to the former it was urged that, however local circumstances might vary, yet, as the hydraulic laws regulating the motion of waves were fixed and immutable, a conclusion could be arrived at, as to the best form of breakwater, first, for the deep-water oscillating wave, and secondly, for the shoal-water wave of translation, or wave of percussion. But on the other hand it was contended, that considerations of cost might frequently lead to the adoption of the less perfect line, and that the comparative suitability, economy, and duration of any hydraulic work were dependent, in a great degree, on the amount of knowledge and skill bestowed on the preliminary survey of the physical features and of the hydraulic phenomena of the locality.

It was thought, that in forming harbours of refuge, the breakwater need not be higher than the level of high-water of equinoctial spring tides, as the object sought to be attained should be to break the great force of storm waves, and not to endeavour to secure such smooth water within, as was required in an interior harbour, and for quays. It was remarked, that the fundamental idea in the construction of the combined timber and stone breakwater at Blyth had been, that the works should rest on and not be attached to the ground, and that its stability should be dependent on its weight, and not on any ground fastening.

This discussion was followed by a Paper "On the River Orwell and the Port of Ipswich," by Mr. G. Hurwood. The several improvements which had been made during the present century were succinctly described; and it was stated that, previous to the commencement of the works, the depth of water at the Ipswich Quay was only 8 feet, whereas now it was 16 feet 4 inches. The object had been to increase the depth by dredging, to bring the channel course into a good condition, and to regulate the capacity where necessary, so as to encourage the easy flow and ebb of the tide, to prevent any encroachment of space previously occupied by tidal water, and, wherever there was an opportunity, to enlarge the receptacle for receiving it.

In the Paper "On the Maintenance and Durability of Submarine Cables in Shallow Waters," Mr. W. H. Preece gave the results of his experience in the maintenance of the cable connecting the Channel Islands with England. It appeared that in little more than two years, this cable had been ruptured in eleven different places. These accidents arose quite unexpectedly, and were attributable, in the Author's opinion, to two causes—the inherent weakness of the cable, and an error of judgment in selecting the route. It was thought that cables should never be trusted to the unseen and unknown action of the bottom of the sea, without the course having first been very carefully surveyed. The oxidation and decay of the cable in different localities were then alluded to, and the plan adopted in repairing the numerous fractures was described. The principles employed in testing, and in calculating the distance and position of faults, were divided into two classes, according as they were dependent upon the laws of resistance, or upon the laws of induction, both of which were minutely considered. In conclusion it was remarked, that as there was no imperfection which could not be detected, and no accident which could not be provided against, it was hoped the discussion of this important question would prove serviceable to the progress of Submarine Telegraphy.

In the course of the discussion, which occupied four evenings, it was remarked, that there were already about thirty undertakings in Submarine Telegraphy, comprising in the aggregate nearly 3,000 miles of cables, a large proportion of which had been at work for many years. As, however, about 9,000 miles of cable had been laid, and nearly 6,000 miles were almost utterly useless, the extension of Submarine Telegraphy had been seriously jeopardized; especially as the failures of the Atlantic and of the Red Sea and India Telegraphs had led to a considerable loss of public money. It was, consequently, of the highest importance to ascertain, if possible, to what causes these failures were due; for as an instantaneous agent for transmitting thought, the Electric Telegraph was as serviceable an invention as the Steam Engine which gave Power, and Railways which supplied the means of Locomotion. It was true that the details of the Atlantic Cable were arranged before anything was practically known about deep-sea cables; but even in this case, in a previous discussion at the Institution,[1] certain precautions had been recommended, which were not acted upon. With regard, however, to the Red Sea and India Telegraph Cable, there was no reason why provision should not have been made to protect the iron from the destructive action of sea-water, and in laying the cable the deep water might have been avoided. Although messages had been transmitted for some months between the separate sections of the cable in the Red Sea, it was admitted that the line had never been worked simultaneously throughout from Suez to Kurrachee. It was believed that the failures of telegraph cables, especially of those laid in deep water, had arisen mainly from the want of sufficient strength, particularly from the absence of an exterior protecting coating; corrosion thus ensued, which might occur from simple oxidation, from the cable lying on a metallic surface, or from the formation of vegetation upon it; and also from the cable not having been thoroughly tested under water, until it was deposited in the ocean. During the manufacture of the Government cable, originally designed to connect Falmouth and Gibraltar, then proposed to be used between Rangoon and

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[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xvii., pp. 221-366.

Singapore, and now laid from Malta to Alexandria, an opportunity was afforded of carrying out a complete system of testing from the first. The plan adopted, which was explained in detail, was stated to depend upon a comparison of resistances. Although resistance coils had been employed since the year 1849, for determining the position of faults in submarine lines, they had not, it was thought, been so used until the period alluded to by the Author. The credit of the invention of resistance coils was given to Professor Wheatstone, who had described them in a Paper to the Royal Society in 1843,[1] and their introduction and useful application in England was due to Mr. Cromwell Varley, by whom they had been used prior to 1852.

It was contended, in the discussion, that the causes of these repeated failures came rather within the scope of the moralist and the man of the world than the man of science, and that the obstacles to success had hitherto been more of a moral than of a mechanical nature.

Mr. Frederick Braithwaite, in his Paper "On the Rise and Fall of the River Wandle; its Springs, Tributaries and Pollution," gave the results of a careful survey of that river made in the year 1853; and during the three evenings over which the discussion was extended, many points of interest were elicited. The topics alluded to were so various, that it is only possible to enumerate some of them. Thus, the proportion of the rainfall flowing off by streams and rivers, and the quantity of water available for water-works purposes, were considered. Also the great fluctuations in the flow, especially in chalk districts, due, it was contended, to the extension of agricultural land drainage. The efforts which had been made to prevent the sewage of Croydon from polluting the River Wandle were then alluded to, and it was asserted that the sanitary condition of that town had been greatly improved, while all had been done that was possible, in the existing state of knowledge, to preserve the purity of the river. This led to a reference to the Sewerage Works at Leicester, as well as to the subject of Sewage Irrigation, which was said to be still "far from solution," and the Stanley Green Works, those at Watford, and at the Craigentenny Meadows (Edinburgh), and at Milan, were alluded to. It was thought that the idea of making the sewage matters of towns commercially useful should, as a rule, be altogether abandoned; and that in future more attention should be paid to the salubrity of the rivers of the country, and to the effect of urban drainage upon them.

The Paper "On the results of Trials of varieties of Iron Permanent Way," by Mr. F. Fox, recorded the experience gained in the use of four modifications of the continuous rolled iron-rail bearer, on the principle introduced by Mr. I. J. Macdonnell, on the Bristol and Exeter Railway. The entire length of line under trial amounted to 14¼ miles of single line, and one portion which had been in wear for eight years was in good condition, and bid fair to continue so for some time. The merits and defects of the system were very fairly stated, and it was remarked, that the maintenance of those portions of the road, laid on the Macdonnell system, cost less than other parts of the same railway. In the course of the discussion a doubt was expressed, whether the continuous wrought-iron way was applicable in stations, or where there were points and crossings; and it was admitted, that the action of frost upon the iron way was one of the difficulties of the system, where the ballast was bad, and the line was not well drained.

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[1] *Vide* Phil. Trans., 1843, p. 312.

The main feature in Mr. Hooper's "Description of the Pier at Southport, Lancashire," was the mode in which the cast-iron columns, for supporting the lattice girders forming the superstructure, were sunk into the sand. This had been accomplished by using a pressure of water of 50 lbs. to the inch, obtained from the Water Company's mains, to remove the sand from under the circular disc with which the bottom of each pile was provided, to form a bearing surface. A similar system had been previously followed with success, in the erection of the Iron Viaducts across the Estuaries Leven and Kent, in Morecambe Bay,[1] by Mr. Brunlees (M. Inst. C.E.), who was also the Engineer of the Southport Pier.

Mr. Bindon B. Stoney, in his Paper "On the Construction of Floating Beacons," after referring to the various forms hitherto employed, particularly to Mr. Herbert's Cone-bottomed Buoy,[2] described a beacon, called the Keel Buoy, in which the sides were prolonged below the bottom, so as to form a circular keel, for retaining a large body of water within it, to give stability and to diminish the tendency to pitch. Seventeen of these Keel Buoys were stated to have been already constructed, and placed in different situations, principally on the coast of Ireland. In the course of the discussion, it was asserted that the Keel Buoy was so trifling a modification of the Cone-bottomed Buoy, introduced by Mr. C. Herbert, as scarcely to be entitled to any great degree of merit.

The Paper by Mr. John Murray, "On the North Sea, with remarks on some of its Friths and Estuaries," contained an account of the changes which had taken place within historic times, on many parts of the east coasts of England and Scotland; as well as of the inroads of the ocean on the whole line of coast from the Schelde to the northern part of Jutland, including particularly Holland and Friesland. The great isolated shoal of the Dogger Bank, situated in the middle of the basin, was attributed to the immense whirl of the stream of flood, and the inference was drawn, that if the tides continued to take their present course, this extensive shoal would ultimately become an island. The effects produced by the action of the tide among the Orkney and the Shetland Isles, in the Pentland Frith, and on the mouths of some of the estuaries of Scotland, were next considered; the Author reserving for a future opportunity his remarks on some of the harbours and rivers of the same coast and of England. In conclusion it was remarked, that the three contiguous Friths of Dornoch, Inverness, and Cromarty, afforded information which might prove useful in designing marine works:—

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[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xvii., p. 442.

[2] *Vide* Ibid., vol. xv., p. 1.

First,—In the Frith of Dornoch, the bar was exposed to the full force of the sea, and no works of an ordinary character could get rid of it in its present situation.

Secondly,—In the Frith of Inverness, the bar had been removed by natural means, well worthy of mature study.

And thirdly,—In the Frith of Cromarty, though there was a bar, yet from the peculiar and happily-placed position of the entrance, it was submerged at such a depth as to be practically of no inconvenience.

The prolonged discussion to which this Paper gave rise, showed that the North Sea possessed features of great interest, whether viewed commercially, or geographically, or as regarded engineering in general, and that its phenomena were worthy of attentive consideration. It was thought, that without stronger currents than at present existed, the Dogger Bank could not be increased to the extent which had been predicted; and that it was doubtful where such material could come from to raise that large bank, equal in area to the principality of Wales, into an island. The variation in the levels of the tides were commented upon, as well as the double tides found at many places round the coast, which were attributed to local rather than to any great oceanic causes; as, for instance, by supposing that one high water was produced by a tidal current along the shore, and the other coming in later from an offing current. It was remarked that this discussion would have a most important result, if it were the means of inducing the authorities to direct the preparation of a contour chart of the sea, within ordinary soundings, all round the British Isles; the Maps being so shaded as to exhibit at a glance the different depths. It was suggested that, as the coast sheets of the Ordnance Map were frequently blank, the contouring of the shores might not be undertaken by that department.

"The Floating Railways across the Forth and Tay Ferries," described in Mr. Hall's Paper, were undertaken for the purpose of establishing an unbroken communication between Edinburgh and the country north of the Tay, by which goods might be conveyed across those ferries, without removal from the waggons. A similar plan might, it was thought, be advantageously adopted in all places where the expense of a bridge, or of a tunnel, offered an insurmountable obstacle, and where the navigation would not admit of the interruption consequent on the erection of a bridge. To allow for the difference in the levels of high and low water, a pier or slip-way was constructed at each side of the ferry, on which traversed a heavy platform, of a wedge shape, the upper surface being always horizontal; to the sea-end of this platform wrought-iron girders were affixed, for spanning the interval between the platform and the stern of the vessel. The vessel itself was provided with standing space for two or three lines of waggons, as required.

The concluding meetings were devoted to the reading and the discussion of a Paper on "The National Defences," by Mr. G. P. Bidder, junior;—a subject of momentous interest at all times, but now of more than ordinary importance, from the vast changes which have taken place of late years, by the universal employment of steam for propulsion in the Royal Navy, by the comparatively recent introduction of arms of precision, in rifles and in artillery, and by the now generally acknowledged necessity of increasing the strength of ships-of-war, by the use of armour-plates.

The Author stated, that his object was not to offer any opinions of his own, but merely to arrange the main questions requiring consideration, so as to facilitate their discussion. First, it was desirable to ascertain, whether reliance should be placed principally upon a powerful Channel fleet, or how far a supplementary protection should be provided, by means of coast fortifications. The insular position and the consequent extensive sea-board of Great Britain seemed to render hopeless, on the score of expense alone, any attempt to protect the shores generally, by means of land fortifications. If it were deemed essential to render the Channel fleet as strong and as effective as possible, it became a question, what description of ships should be built for that purpose, and what materials should be employed in their construction, having regard to the modern improvements in gunnery, and to the application of steam power to propulsion. The objections to the use of iron, hitherto asserted to be unfitted for naval purposes, were then examined, and its advantages were stated to be, the greater strength attainable, the comparatively little repair and renovation required, and the freedom from danger of injury or loss by fire; added to which there was an inexhaustible supply of iron in this country, as well as the skilled labour for producing iron ships to any extent, whilst there was an increasing scarcity of timber, suitable for ship-building purposes. The fortification of ships-of-war, by means of iron plates, was next commented on, illustrated by remarks on the French vessel 'La Gloire' and the English ship the 'Warrior.' In conclusion, the practicability and advisability of constructing steam rams, and the best mode of dealing with the present navy, and of converting the old men-of-war into efficient ships, were considered.

The extensive range of subjects thus briefly enumerated, no less than the magnitude of the questions involved, naturally led to much discussion. And although, at one time, it might have been thought, that such topics were not appropriate for the Institution of Civil Engineers, yet when it was taken into consideration, how much mechanicians had to do with the manufacture of artillery and of small arms, and with the construction of ships and their machinery, it was believed that there was no place where these subjects could be more beneficially and instructively discussed; especially as they could be considered quite apart from the art of warfare.

It will not be necessary to dwell at length upon the discussion to which this Paper gave rise, as a full report of the proceedings has already been printed and circulated. It will suffice to say, that it was strongly urged, that if the command of the narrow seas surrounding these islands was not maintained, all source of national glory and prosperity would be lost. It was argued, that as the Channel fleet must be free to move wherever it was required, an enemy might, during the temporary absence of that fleet, effect a landing upon the coast; and hence the inference that the arsenals of construction, repair, and maintenance, forming the naval base, should at least be fortified. But, on the other hand, it was contended, that in future the arsenals on the sea-board should comprise only the fitting-shops, and that the factories for the supply of the armament and for the large renewals should be placed inland.

Sir William Armstrong took advantage of this opportunity to continue his former observations,[1] upon the subject of the rifled artillery in use in her Majesty's service. He commented upon the objections which had been made to the leaden coating of the projectile, and then proceeded to explain various specimens of projectiles which were exhibited; and he also described the new sea-service fuze, which had been called the 'pillar fuze,' a muzzle-loading gun, called the 'shunt gun,' as well as a model of the breech of a 100-pounder gun, in which the breech-closing apparatus was worked from the side.

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[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xix., p. 407.

In preparing the list of subjects for Premiums for the session 1861-62, it has been determined, with a view of encouraging the production of really valuable original communications, to add to the list certain pecuniary awards, in addition to the Honorary Premiums, for a limited number of Papers of distinguished merit. In this instance the pecuniary awards are not to exceed twenty-five guineas each, and the subjects selected are five in number, but it is expressly stated, that other Papers, if of adequate merit, will be taken into consideration by the Premium Committee. The subjects referred to are:—

On Reclaiming Land from Seas and Estuaries.
Accounts of existing Water-works; showing the methods of supply, the distribution throughout the streets of Towns, and the general practical results.
On the results of the use of Tubular Boilers, and of Steam at an increased pressure, for Marine Engines, noticing particularly the difference in weight and in speed, in proportion to the Horse Power and the Tonnage.
On the Form and Materials for Floating Batteries and Iron-plated Ships ('Frégates blindées'), and the points requiring attention in their construction.
Railway Accidents—their causes and means of prevention; showing the bearing which existing legislation has upon them.

The remaining subjects are, with a few exceptions, much the same as those to which attention has been directed for several years; as but few communications have been received in answer to the lists issued from time to time. They are still retained, because it is believed that experience has been gained in the practical conduct of actual works, which it is very desirable should be recorded, but upon which, at present, it is difficult to find any published information. Many important works, involving considerable novelty, have been executed by Members of the Institution, both at home and abroad, which have never been described, except perhaps in foreign scientific periodicals. Several of the subjects are of a more general character, upon which the information, at present obtainable, is so scattered and unconnected as to be practically valueless.

It would be very useful, if every acting and resident Engineer, on the completion of any undertaking upon which he may have been engaged, would prepare and present to the Institution a descriptive narrative of the progress of the works, of any peculiarities in their design, and more particularly of any incidents that may have occurred during their construction.

The Council would remind all those who have joined the Institution within the last few years, of the engagement they signed upon being elected,—"to present to the Institution an Original Communication, Drawing, Plan, or Model of Engineering interest, or some scientific work for the library, within the space of twelve months from the date of election." As the position and utility of the Institution are dependent on the individual efforts of the Members and Associates, it is clear that this regulation is very necessary, and is calculated, if enforced, to give to all who join the Institution a direct, personal interest in its proceedings. The Council hope that all those Members and Associates who have not hitherto presented Papers, will be induced to comply at once with the terms of their engagements.

It will be within the recollection of the Members, that in the last Report it was stated that application had been made to the Lords Commissioners of her Majesty's Treasury, to complete the series of Ordnance Maps of the United Kingdom now in possession of the Institution, to which no additions had been received for several years, and also to direct that the maps illustrating the geological survey of the British Isles, with which considerable progress has been made, should likewise be forwarded for the use of the Members. In reply their Lordships stated that "on the recommendation of the late Board of Ordnance, in 1850, the gratuitous supply of the ordnance maps to societies and institutions in general was discontinued, and my Lords regret that they cannot make the Institution of Civil Engineers an exception to the rule then adopted, and which continues to be enforced in other cases." Under these circumstances nothing further has been done, as it was felt that it would not be prudent at the present time to incur so large an expenditure as their purchase would involve, when, for the same sum of money, so many books, atlases and general maps could be obtained, which were likely to be more generally useful. If, at some future time, it should appear probable that the Lords of her Majesty's Treasury might be induced to withdraw this restriction, a strong representation will again be made.

It will have been noticed by those visiting the Library, that during the year, Maps of Europe (both topographical and geological), England, Scotland, Ireland, India, the United States, and Canada, have been acquired; and that spaces have been left for a Map of the World and a Map of Asia, which will be added, as soon as the new editions at present in hand have been completed. With regard to books, a commencement has been made, by the purchase of a few standard atlases, and of French and English works, particularly to complete series hitherto imperfect. But it is hoped, that the funds will in future admit of a greater outlay being incurred in this department. This year's account will show, that the main charges for the library have been for binding, and for the purchase of maps and atlases. Although the number of books thus acquired is limited, much useful information has been collected, especially from the Continent, which will facilitate future purchases. Thus, there has been obtained from the Ecole des Ponts et Chaussées a carefully prepared and classified catalogue of books upon public works, such as are recommended by the school for its pupils, and to the Engineers in that department; and from the Royal Institution of Civil Engineers of Holland a marked catalogue of scientific books, principally on water construction, has been received. Communications have also been opened, which it is hoped will lead to similar lists being procured of German and Italian works. It will then be for successive Councils to take advantage of the information so obtained, with the view of making the Library of the Institution unrivalled in its peculiar specialty. It should contain copies of all treatises on engineering subjects and the allied sciences, wherever published. For instance, it is particularly desirable that the library should be rich in French books on engineering; that a complete collection should be obtained of the best Italian works on hydraulics; and that endeavours should be made to procure a good set of old military engineering works, as containing the first examples of Civil Engineering proper.

The accessions to the Library by gift have been numerous. These have on several occasions been brought under the notice of the Members at the weekly meetings, so that it will be unnecessary to repeat them here; and while the thanks of the Institution are due, and have been presented, to all the donors, they are particularly so to General Sabine, Colonel Sir Proby Cautley, K.C.B., Colonel Sir Henry James, C.B., Captain Washington, R.N., Sir Roderick Murchison, Professor Airy, and Messrs. James Hodges, W. W. Collins, Andrew Cutbill, Nicholas Wood, J. S. Crossley, Bennet Woodcroft, J. R. McClean (Vice-President), and H. P. Stephenson, for the valuable presents they have made.

With regard to the proceedings of other societies, particularly of those of an engineering character, endeavours have been made to extend the system of mutual interchange, and it may be stated that during the year the series of the Society of Engineers of France, of the Annales des Ponts et Chaussées, of the Royal Netherlands Institute of Engineers, and of the Franklin Institute have, among many others, been rendered complete, and been bound, so as to be available for consultation and reference. In effecting these interchanges the assistance of M. Cavalier, Director of the Ecole des Ponts et Chaussées should be specially noticed.

The abstract of the Receipts and Expenditure attached to this Report shows, that the amount received from Subscriptions and

Fees is greater than in any previous year; and that the item Current Subscriptions, which may be looked upon as the regular income, has been steadily increasing year by year, and is now 50 per cent. in excess of what it was in 1851. The Stephenson, the Miller and the Institution funds have also contributed to swell the receipts by upwards of £150. With regard to the expenditure, the establishment charges will be found to be, if anything, rather less than usual. On the Library the disbursements have been considerable, arising from the purchase of new books and maps, and from the binding of a large number of serial works, including 'Transactions of Societies.' During the year the Stephenson and the Miller Bequests have been invested in Four per Cent. Debenture Stocks in the North Eastern, the Lancashire and Yorkshire, and the Norfolk Railway Companies. The Institution Fund has also been added to, by the purchase of £900 of similar stock in the Norfolk Railway Company. The investments now stand:—

INVESTMENTS.

	£.	s.	d.	£.	s.	d.
Telford Fund—Three per Cent. Consols .	2,551	15	10			
„ Three per Cent. Annuities .	2,342	17	1			
				4,894	12	11
Manby Fund—Norfolk Railway Company, Five per Cent. Stock				200	0	0
Stephenson Bequest—North Eastern Railway Company, Four per Cent. Stock				2,000	0	0
Miller Fund—Lancashire and Yorkshire Railway Company, Four per Cent. Stock	2,000	0	0			
„ Norfolk Railway Company, Four per Cent. Stock	1,100	0	0			
				3,100	0	0
Institution Investments—Norfolk Railway Company, Four per Cent. Stock				2,000	0	0
				£12,194	12	11

	£.	s.	d.	£.	s.	d.
The balance on deposit at the Union Bank, after the purchase of these different Stocks, was £222. 19s. This has been increased by the withdrawal of £1,000 from the Bankers, making the total on deposit on the General Account . . .	1,221	19	0			
Ditto on the Building Fund Account . .	911	17	1			
				2,133	16	1
The Current Balance at the Bankers', Messrs. Coutts & Co., at the close of the Financial Year was				668	9	7
				£2,802	5	8

So that the funded investment and the available cash balances together amount to nearly £15,000, and there is a further sum of £2,000 still to be received under the will of the late Mr. Joseph Miller.

On the death, in October last, of Mr. Ritherdon, who for fifteen years held the appointment of Cashier and Collector to the Institution, the retiring allowance of £50 per annum enjoyed by him ceased.

The amount of arrears of Subscriptions for 1861, due November 30th, is,—

	£.	s.	d.	£.	s.	d.
From Members of all classes, residing abroad .	52	10	0			
From Members of all classes, residing in the United Kingdom	189	0	0			
				241	10	0

The amount of arrears for the years 1859 and 1860 was—

From Members of all classes, residing abroad .	26	5	0			
From Members of all classes, residing in the United Kingdom	63	0	0			
				89	5	0
				£330	15	0

Great exertions have been made to reduce the amount of arrears of Subscriptions. In some instances the sums due have been paid in full, while in others a composition has been accepted. Still, however, the Council regret to have to report that they have been under the painful necessity of erasing from the Register the names of one Member, nineteen Associates, and two Graduates, in accordance with the provisions of Clause 10, Section V., of the Bye-Laws.

The tabular statement of the transfers, elections, deceases, and resignations, of Members of all classes during the years 1859-60 and 1860-61, taking into consideration the names which have been erased from the Register, appears thus:—

—	Honorary Members.	Members.	Associates.	Graduates.	Annual Increase.
1859-60.					
Transferred to Members . .	..	..	13		
Elections	..	23	39	..	62 − 26 = 36
Deceases	1	12	7	..	26
Resignations	..	1	5	..	
1860-61.					
Transferred to Members . .	..	..	2		
Elections	..	24	45	..	69 − 54 = 15
Deceases	2	9	12	..	54
Resignations	..	2	7	..	
Erased from the Register . .	..	1	19	2	
Members of all Classes on the Books, November 30, 1861.	22	369	542	12	945

This statement shows, that the numbers of the Members and Associates, who compose the great bulk of the Institution, stand in the proportion of 2 to 3 respectively. It may also be mentioned, that in the last quarter of a century, the number of members of all classes has increased four-fold.

If the Honorary Members and Graduates are omitted from the calculation, the annual increase of Members and Associates stands thus:—

Years.	Members Elected.	Associates Elected.	Total Elected.	Deceases, Resignations, and Erasures.	Effective Increase.
1856	10	24	34	24	10
1857	12	57	69	23	46
1858	11	25	36	13	23
1859	16	41	57	20	37
1860	23	39	62	25	37
1861	24	45	69	50	19

The following Members and Associates having tendered their resignations, have been permitted to retire from the Institution:—Messrs. Matthew Bullock Jackson, and Edwin Octavius Tregelles, Members; Messrs. Charles Robert Drysdale, Richard Rous Ellicombe, John Scott, Charles Christopher Gustave Holtze, Captain Christopher Claxton, R.N., Sir Cusack Patrick Roney, and Lieutenant-Colonel James Chicheley Plowden, Associates.

The deceases during the past year have been:—Mr. Eaton Hodgkinson, and General Sir Charles William Pasley, Honorary Members; Messrs. William Alleard, Samuel Clegg, Nicholas Harvey, Joseph Maudsley, John M'Veagh, John Plews, James Ralph Walker, John Ward and Sir William Cubitt, Members; Messrs. George Aitchison, James Braidwood, Charles Frederick Cheffins, Octavius Cockayne, Charles Cowper, Henry Alcock Fletcher, Lionel Gisborne, William Newton, John Pigott Smith, Edmund Treherne, John Neville Warren, and Colonel Robert Kearsley Dawson, R.E., C.B., Associates.

The Memoirs of our late friends will be found in the Appendix to this Volume.

In preparing the balloting list for the Election of Officers, Mr. Hawkshaw, the senior Vice-President in duration of office, has been nominated for President, in succession to Mr. Bidder.

The vacancy thus created among the Vice-Presidents has been filled up by the selection of Mr. J. E. Errington, the senior Member of Council. The former Members of Council are proposed for re-election, but the two Associates retire annually. As, however, the Bye-Laws require that the List shall contain the names of twelve Members and four Associates, although only ten and two respectively can be elected annually, there have been added the names of Messrs. Abernethy, Bateman, and Vignoles, Members, and Messrs. Cochrane, Marrable, Leather, and Col. Simmons, R.E., Associates, all of whom have consented to serve if elected.

In closing this Report the Council would emphatically repeat, that the success of the Institution depends a great deal more upon the individual exertions of the Members in support of its scientific character, than upon its pecuniary prosperity; and that it cannot continue to hold the high position it has already attained, without efforts and sacrifices being made by the present Members, similar to those which were so unremittingly and so freely incurred by their predecessors.

ABSTRACT *of* RECEIPTS *and* EXPENDITURE

RECEIPTS.

Dr.	£.	*s.*	*d.*	£.	*s.*	*d.*
To Balance in the hands of the Treasurer				233	6	5
— Subscriptions and Fees:—						
Arrears	278	16	0			
Current	2,227	1	0			
Subscriptions, 1862 (in advance)	12	12	0			
Fees	214	4	0			
Life	96	1	6			
				2,828	14	6
— Publication Fund				44	18	10
— Council Premium Fund				57	3	0
— Publications:—Sale of Transactions				68	17	8
— Telford Fund:—						
Dividends—6 Months, due Christmas, 1860, on £2,551. 15*s.* 10*d.*, Three per Cent. Reduced Consols	36	13	8			
Ditto, 6 Months, due Lady-day, 1861, on £2,342. 17*s.* 1*d.*, Three per Cent. Reduced Consols	33	13	7			
Ditto, 6 Months, due Midsummer, 1861, on £2,551. 15*s.* 10*d.*, Three per Cent. Reduced Consols	36	16	10			
Ditto, 6 Months, due Michaelmas, 1861, on £2,342. 17*s.* 1*d.*, Three per Cent. Reduced Consols	33	16	6			
				141	0	7
— Manby Fund:—						
1 Year's Dividends on £200, Norfolk Railway Company, Five per Cent. Stock				9	12	1
— Stephenson Bequest:—						
Deposit Interest on £2,000, from Oct. 24 to Dec. 31, 1860	14	6	6			
72 Days' Interest on £2,000, North Eastern Railway Company, Four per Cent. Debenture Stock, purchased by order of Council, April 9, 1861	15	3	9			
				29	10	3
— Miller Fund:—						
Deposit Interest on £3,000, from Oct. 24 to Dec. 31, 1860	21	9	8			
73 Days' Interest on £2,000, Lancashire and Yorkshire Railway Company, Four per Cent. Debenture Stock, purchased by order of Council, April 9, 1861	15	7	11			
6 Months' Dividends on £1,100, Norfolk Railway Company, Four per Cent. Debenture Stock, purchased by order of Council, April 9, 1861	21	3	6			
				58	1	1
— Institution Investments:—						
1 Year's Dividends on £1,100, Norfolk Railway Company, Four per Cent. Debenture Stock, purchased by order of Council, Jan. 31, 1860	42	5	2			
Deposit Interest on £1,000, from May 1 to Dec. 31, 1860	16	13	10			
6 Months' Dividends on £900, Norfolk Railway Company, Four per Cent. Debenture Stock, purchased by order of Council, April 9, 1861	17	6	6			
Deposit Interest on £1,221. 19*s.*, from April 30 to June 30, 1861	8	17	6			
				85	3	0
				£3,556	7	5

from the 1st DEC. 1860, *to the* 30th NOV., 1861.

PAYMENTS.

Cr.	£.	*s.*	*d.*	£.	*s.*	*d.*
By House, Great George Street:—						
Rent	361	5	10			
Taxes	40	1	5			
Insurance	18	19	9			
				420	7	0
— Salaries				400	0	0
— Donation to late Cashier and Collector				50	0	0
— Clerk, Messengers, and Housekeeper				164	17	0
— Postage and Parcels:—						
Postage	32	12	0			
Parcels	0	12	3			
				33	4	3
— Stationery, Engraving, Printing Cards, Circulars, &c.				57	0	2
— Coals, Candles, Oil, and Gas:—						
Coals	16	4	0			
Oil	1	18	6			
Gas	16	0	10			
				34	3	4
— Tea and Coffee				30	15	11
— Library:—						
New Books	57	15	4			
Binding Books	109	2	10			
Maps	69	11	6			
Periodicals	20	12	9			
Charges	6	13	10			
				263	16	3
— Publication, Minutes of Proceedings				267	19	0
— Telford Premiums				16	5	0
— Council Premiums				36	13	11
— Watt Medal				2	1	0
— Manby Premium				14	4	6
— Diplomas				15	2	7
— Manuscripts, Original Papers, and Drawings				4	1	1
— Winding and Repairing Clocks				2	0	6
— Incidental Expenses:—						
Gratuities and Christmas Gifts	1	15	0			
Occasional Assistance	2	2	8			
Assistance at Meetings	8	12	6			
Royal Gun Factory—Carriage of Armstrong Guns to and from Inst. C.E.	9	19	4			
Beating Carpets	1	14	0			
Household Utensils, Repairs, and Expenses	29	18	0			
Insurance on Pictures at Conversazione	5	6	0			
Bad Money	5	0	0			
				64	7	6
				1,876	19	0
— Deposit at Union Bank	1,000	0	0			
— Balance of Petty Cash, Nov. 1, 1861, in the hands of the Secretary	10	19	2			
— Balance in the hands of the Treasurer	668	9	3			
				1,679	8	5
				£3,556	7	5

Examined and compared the above Account with the Vouchers and the Cash Book, and find them to be correct, leaving a Balance in the hands of the Treasurer of Six Hundred and Sixty-eight Pounds, Nine Shillings, and Three Pence.—Nov. 30th, 1861.

(Signed) WILLIAM JOSEPH KINGSBURY, } *Auditors.*
FRANK C. STILEMAN, }
JAMES FORREST, *Secretary.*

December 7th, 1861.

PREMIUMS AWARDED.

SESSION 1860-61.

THE COUNCIL of the Institution of Civil Engineers have awarded the following Premiums:—

1. A Telford Medal, and a Council Premium of Books, to William Henry Preece, Assoc. Inst. C.E., for his Paper "On the Maintenance and Durability of Submarine Cables in Shallow Waters."
2. A Telford Medal, and the Manby Premium, in Books, to George Parker Bidder, junior, M.A., Assoc. Inst. C.E., for his Paper on "The National Defences."
3. A Telford Medal, to Francis Fox, M. Inst. C.E., for his Paper "On the Results of Trials of Varieties of Iron Permanent Way."
4. A Council Premium of Books, to Frederick Braithwaite, M. Inst. C.E., for his Paper "On the Rise and Fall of the River Wandle; its Springs, Tributaries, and Pollution."
5. A Council Premium of Books, to George Hurwood, M. Inst. C.E., for his Paper "On the River Orwell and the Port of Ipswich."
6. A Council Premium of Books, to William Hall, Assoc. Inst. C.E., for his Paper "On the Floating Railways across the Forth and Tay Ferries, in connexion with the Edinburgh, Perth, and Dundee Railway."

[SUBJECTS

SUBJECTS FOR PREMIUMS.

SESSION 1861-62.

THE COUNCIL invite communications on the following, as well as other subjects, for Premiums.

For a limited number of Papers of distinguished merit, pecuniary awards will be made, not exceeding in each case Twenty-five Guineas, in addition to the Honorary Premiums. The subjects numbered 4, 19, 28, 32, and 55, have been selected as those upon which, it is hoped, such communications may be received during the ensuing Session. But Papers on other subjects, if of adequate merit, will be taken into consideration, in the adjudication of the pecuniary awards.

1. On the Principles upon which the Works for the Improvement of River Navigation should be conducted, and the effects of the works upon the Drainage and Irrigation of the District; including accounts of the Systems of Moveable Dams ('Barrages Mobiles') in Rivers on the Continent.
2. On the effect of Engineering Works in causing injurious Scour, Flooding, or Silting-up, in Tidal Estuaries, or Rivers.
3. On the effect of Sluicing, in removing and preventing deposits, at the Entrances of the Docks on the Coast and in Tidal Rivers.
4. On Reclaiming Land from Seas and Estuaries. (Twenty-five Guineas.)
5. On the Results of the Employment of Steam Power on Canals, and of other measures for the Improvement of Canals as a means of conveyance for heavy traffic.
6. On the Method of constructing Foundations, for large Structures, in deep water; and on the various systems of Driving Piles.
7. Description of Cast, or Wrought, Iron Cranes, Scaffolding and Machinery, employed in large works, in Stone Quarries, as Hoists, or Lifts on Quays, in Warehouses, &c., especially where either Steam or Water, is used as a motive power.
8. The Selection of Sites for the Construction of Docks on the course of Tidal Streams, with reference to communication with Railways, and with Inland Navigation.

9. The Selection of Sites for, and the Principles of the construction of, Breakwaters, Harbours of Refuge, Piers, Moles (whether solid, or on arches), Sea Walls, and Shore Defences; illustrated by examples of actual works.
10. On the arrangement and Construction of Floating Landing-Stages, for passenger and other traffic.
11. The construction of Lighthouses, their Machinery and Lighting Apparatus; with notices of the methods in use for distinguishing the different Lights.
12. On the Mechanical Methods of Boring and of Sinking large Shafts, of introducing the Tubbing and the impervious lining, and of traversing running sand and other difficult strata.
13. The Results of Contrivances for facilitating the Driving of Tunnels, or Drifts in Rock.
14. Accounts of the various modes adopted for Moving Earth in Tunnels, Cuttings, or embankments, with the cost.
15. On the different systems of Swing, Lifting, and other opening Bridges, with existing examples.
16. On the construction of Suspension Bridges, with rigid platforms, and the modes of Anchoring the Stay-chains.
17. The Results of a series of Observations on the Flow of Water from the Ground, in any large district; with accurately-recorded Rain-Gauge Registries, in the same locality, for a period of not less than twelve months.
18. On the Construction of Catch-water Reservoirs in Mountain Districts, for the supply of Towns, or for Manufacturing purposes.
19. Accounts of existing Water-works; showing the methods of supply, the distribution throughout the streets of Towns, and the general practical results. (Twenty-five Guineas.)
20. The comparative Duty performed by, and improvements in the construction of, modern Pumping Engines for raising Water, for the supply of Towns, or for the Drainage of Mines; noticing in the latter case, the depth and length of the underground workings, the height of the surface above the sea, the geological formation, the contiguity of streams, &c.
21. The Results of the use of Bucket and Rotary Pumps, for lifting large quantities of water to a limited height, as at the Haarlem Meer, or at Whittlesea Mere, or for the purposes of Irrigation; with descriptions of the Machinery employed, and the application of such Machinery to the raising of the sewage of large Towns.
22. The Drainage and Sewerage of large Towns; exemplified by accounts of the systems at present pursued, with regard to

the level and position of the outfall, the form, dimensions, and material of the sewers, the prevention of emanations from them, the arrangements for connecting the house-drains with the public sewers, and the disposal of the sewage, whether in a liquid form, as irrigation, or in a solid form after deodorisation.

23. On the Means of Rendering large supplies of Water available for the purpose of Extinguishing Fires, and the best application of Power to the Working of Fire Engines.
24. On Boiler Inspection as practised in this country and on the Continent, with remarks as to the comparative merits of the two systems.
25. On the Causes of the alleged Failure in Economising Fuel in working Steam expansively, and the probable conditions for ensuring success.
26. On the Results of the use of Superheated Steam, and of Surface Condensation.
27. On Substitutes for Steam, and the Causes of their Failure.
28. On the Results of the use of Tubular Boilers, and of Steam at an increased pressure for Marine Engines, noticing particularly the difference in Weight and in Speed, in proportion to the Horse Power and the Tonnage. (Twenty-five Guineas.)
29. On the Measure of Resistance to Steam Vessels at high Velocities.
30. The Substitution of Machinery for Manual Labour, for Raising, Lowering, and Reefing the Sails, Weighing the Anchor, &c., on board ship.
31. On Steam Vessels of Light Draught for the Shallow Rivers of India, &c.
32. On the Form and Materials for Floating Batteries and Iron-plated Ships ('Frégates blindées'), and the points requiring attention in their Construction. (Twenty-five Guineas.)
33. On the Construction of Rifled and Breech-loading Artillery; and on the Initial Velocity, Range, and Penetration of Rifled Projectiles, and the influence of Atmospheric Resistance.
34. Description of Street Railways and Carriages, as used in the United States of America, in Paris, and elsewhere, with the Results.
35. Improvements in the Construction of Railway Carriages and Waggons, with a view to the reduction of the gross weight of Passenger and Goods Trains; also of Railway Wheels, Axles, Bearings, Axle-Boxes, and Breaks, and of Bearing,

Traction, and Buffer Springs; treating particularly their ascertained duration and their relative friction.

36. Descriptions of the various kinds of Machinery in use in the principal Shipping Ports, for the Shipment of Coal; noticing particularly those in which the greatest expedition is combined with the least amount of breakage of the Coal; and also accounts of the means of unshipping and measuring, or weighing the Coal, on its arrival in Port.
37. On the means of Utilising the products of the Distillation of Coal, so as to make Coke commercially as cheap as Coal; with descriptions of the Ovens, and of the best processes used in Great Britain and on the Continent, in the manufacture of Coke.
38. The Precautions to be adopted for guarding against Accidents by Fire-damp and After-damp in Mines.
39. The Chemical Analysis, and the Application to economic purposes, of the Gases generated in Iron Blast-Furnaces.
40. Description of Modifications of the present systems of Smelting Iron Ores, of Improvements in the Conversion of Cast Iron into the malleable state, and of the Manufacture of Iron generally, comprising the distribution and management of Iron Works.
41. Improvements in the Manufacture of Iron for Rails and Wheel Tyres, having special reference to the increased capability of resisting lamination and abrasion; and accounts of the Machinery required for rolling heavy Rails, Shafts, and Bars of Iron of large sectional area.
42. On the Construction and Application of Steam Hammers.
43. On the use of Steel Bars and Plates in Engine-work and Machinery, for Boilers and for Ship-building.
44. The Process of Manufacture, and mode of treatment, of Aluminium.
45. On the Forms and Dimensions of Journals of Machine Shafts, Axles, &c.; with the best Composition for the linings of Bearings, and the most approved methods of Lubricating.
46. On the Mechanism of Astronomical Instruments.
47. On Machinery adapted for the better Separation of the various Substances found in combination with Metallic Productions.
48. On the Substitution of Machinery for Manual Labour in Mining Operations; and on Hydraulic Machinery in Mines.
49. On the Improvements which may be effected in the Buildings, Machinery, and Apparatus, for producing Sugar from the Cane in the Plantations and Sugar Works of the British

Colonies, and the Comparison with Beet Root, with regard to quantity, quality, and economy of manufacture.
50. Accounts of Improvements in Flax and Cotton Machinery, and in the processes of preparing those substances for manipulation.
51. An account of the mechanical means at present in use for facilitating the operation of Packing Materials and Goods, whether by Hydraulic Power, or otherwise.
52. The uses of Vulcanised, or Mineralised Caoutchouc; the means of increasing its durability, and the modes of causing its adhesion to metal.
53. On the Application of Photography to Engineering.
54. On the Application of the Electric Telegraph to Railway Train Signalling.
55. Railway Accidents—their Causes and Means of Prevention; showing the bearing which existing Legislation has upon them. (Twenty-five Guineas.)
56. Memoirs and Accounts of the Works and Inventions of any of the following Engineers:—Sir Hugh Myddleton, Arthur Woolf, Jonathan Hornblower, Richard Trevithick, William Murdoch (of Soho), Alexander Nimmo, and John Rennie.

Original Papers, Reports, or Designs, of these, or other eminent individuals, are particularly valuable for the Library of the Institution.

The competition for Premiums is not confined to Members, or Associates of the Institution, but is equally open to all persons, whether Natives, or Foreigners.

The Council will not consider themselves bound to award any Premium, should the communication not be of adequate merit, but they will award more than one Premium, should there be several communications on the same subject deserving this mark of distinction.

The communications must be forwarded, on or before the 1st of January, 1862, to the house of the Institution, No. 25, Great George Street, Westminster, S.W., where copies of this Paper and any further information, may be obtained.

CHARLES MANBY, *Honorary Secretary.*
JAMES FORREST, *Secretary.*

25, *Great George Street, Westminster, S.W.,*
July, 1861.

NOTICE.

It has frequently occurred, that in Papers which have been considered deserving of being read and published, and have even had Premiums awarded to them, the Authors may have advanced somewhat doubtful theories, or may have arrived at conclusions at variance with received opinions. The Council would, therefore, emphatically repeat, that the Institution must not, as a body, be considered responsible for the facts and opinions advanced in the Papers, or in the consequent Discussions; and it must be understood, that such Papers may have Medals and Premiums awarded to them, on account of the Science, Talent, or Industry displayed in the consideration of the subject, and for the good which may be expected to result from the discussion and the inquiry; but that such notice, or award, must not be considered as any expression of opinion, on the part of the Institution, of the correctness of any of the views entertained by the Authors of the Papers.

EXTRACTS FROM THE MINUTES OF COUNCIL, FEB. 23rd, 1835.

"The principal subjects for which Premiums will be given are:—

"1st. Descriptions, accompanied by Plans and explanatory Drawings, of any work in Civil Engineering, as far as absolutely executed; and which shall contain authentic details of the progress of the Work. (Smeaton's Account of the Edystone Lighthouse may be taken as an example.)

"2ndly. Models, or Drawings, with descriptions of useful Engines and Machines; Plans of Harbours, Bridges, Roads, Rivers, Canals, Mines, &c.; Surveys and Sections of Districts of Country.

"3rdly. Practical Essays on subjects connected with Civil Engineering, such as Geology, Mineralogy, Chemistry, Physics, Mechanic Arts, Statistics, Agriculture, &c.; together with Models, Drawings, or Descriptions of any new and useful Apparatus, or Instruments applicable to the purposes of Engineering or Surveying."

EXCERPT BYE LAWS, SECTION XIV., CLAUSE 3.

"Every Paper, Map, Plan, Drawing, or Model presented to the Institution, shall be considered the property thereof, unless there shall have been some previous arrangement to the contrary, and the Council may publish the same, in any way and at any time they may think proper. But should the Council refuse, or delay the publication of such Paper, beyond a reasonable time, the Author thereof shall have a right to copy the same, and to publish it as he may think fit, having previously given notice, in writing, to the Secretary of his intention. No person shall publish, or give his consent for the publication of any communication presented and belonging to the Institution, without the previous consent of the Council."

INSTRUCTIONS FOR PREPARING COMMUNICATIONS.

The Communications should be written in the impersonal pronoun, and be legibly transcribed on foolscap paper, about thirteen inches by eight inches, the lines being three-quarters of an inch apart, on the one side only, leaving a margin of one inch and a-half in width on the left side, in order that the sheets may be bound.

The Drawings should be on mounted paper, and with as many details as may be necessary to illustrate the subject, and should be to such a scale that they may be clearly visible, when suspended on the walls of the Theatre of the Institution, at the time of reading the communication, or enlarged Diagrams may be sent for the illustration of any particular portions.

Reduced Drawings for the illustrative Plates and Woodcuts will be required, as soon as the Papers are accepted.

Papers which have been read at the Meetings of other Scientific Societies, or have been published in any form, cannot be read at a Meeting of the Institution, nor be admitted to competition for the Premiums.

ORIGINAL COMMUNICATIONS,

DRAWINGS, PRESENTS, &c.,

RECEIVED BETWEEN JUNE 30, 1861, AND JUNE 29, 1862.

ORIGINAL COMMUNICATIONS.

AUTHORS.

Bidder, G. P., Jun. No. 1,038.—The National Defences.

Blyth, E. L. J. No. 1,039.—Description of the Lock Ken Viaduct on the Portpatrick Railway. With two Drawings.

Bremner, A. No. 1,042.—Account of the means adopted for Raising and Floating the iron steam-ship 'Great Britain,' stranded in Dundrum Bay, Ireland, in September, 1846, and recovered in August, 1847. With a series of Diagrams.

Fox, F. No. 1,032.—On the Results of Trials of Varieties of Iron Permanent Way. With a series of Diagrams.

Hall, W. No. 1,036—On the Floating Railways across the Forth and Tay Ferries; in connexion with the Edinburgh, Perth, and Dundee Railway. With a series of Diagrams.

Harrison, J. T. No. 1,034.—On the Ventilation of Mines.

Hooper, H. No. 1,033. Description of the Pier at Southport, Lancashire. With a series of Diagrams.

Murray, J. No. 1,033.—On the North Sea; with remarks on some of its Friths and Estuaries. With a series of Plans, Diagrams, and Maps.

Preece, W. H. No. 1,030.—On the Maintenance and Durability of Submarine Cables in Shallow Waters. With a series of Diagrams.

[CATALOGUE

CATALOGUE OF PRESENTS.

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——— The Militia of the United Kingdom; with suggestions for the permanent organization of the Force, with Military Sketch Map. By Lt.-Col. Shafto Adair. Tract. 8vo. London. No date.

——— The Organization and Duties of the Militia of the United Kingdom considered with reference to Invasion. In a Lecture delivered before the Council of the United Service Institution, and in a Paper contributed to the Cambridge Essays. By Colonel Shafto Adair. Tract. 8vo. Map. London. No date.

Airy, G. B. Astronomical Observations, made at the Royal Observatory, Greenwich, by Maskelyne, from the year 1765 to 1798. 3 Vols. Folio. London, 1776-99.

——— Ditto, during the years 1829, Part V.; 1830, Part V.; 1831, Parts III., IV., and V.; 1832, 1833, 1834 and 1835. Under the direction of John Pond. Folio. London, 1829-36.

——— Ditto, during the years 1836 to 1847. Under the direction of G. B. Airy. 4to. London, 1837-48.

——— Appendix to the Greenwich Observations, 1837. 4to. London, 1838.

——— Astronomical, Meteorological, and Magnetical Observations, made at the Royal Observatory, Greenwich, during the years 1848 to 1858. Under the direction of G. B. Airy. 4to. London, 1848-58.

——— Bessel's Refraction Tables, modified and expanded. 4to. London, 1855.

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———	Reduction of the Observations of Planets, made at the Royal Observatory, Greenwich, from 1750 to 1830. Under the superintendence of G. B. Airy. Folio. London, 1845.
———	Ditto of the Moon, from 1750 to 1830. 2 Vols. 4to. London, 1848.
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———	Reports of the Astronomer Royal to the Board of Visitors for the years 1836 to 1860. 4to. Greenwich, 1836-60.
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———	Sitzungsberichte. 1860. Heft I. II. and III., and 1861, Heft 1. 8vo. München, 1860-61.
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——— Vorträge über Artillerie. Ginleitung in die Balistik. Von J. Hartmann. 8vo. Cuts. Hannover, 1861.

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[OFFICERS.

OFFICERS.—1861-62.

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January 14, 1862.

JOHN HAWKSHAW, President, in the Chair.

THE following Candidates were balloted for and duly elected:—ALEXANDER LUDERS LIGHT, JAMES ROBERT MOSSE, JOHN CHALONER SMITH, as Members; and LORD RICHARD GROSVENOR, M.P., HENRY ARTHUR HUNT, Junior, and HERBERT HOWARD KEELING, as Associates.

Mr. HAWKSHAW addressed the Meeting in the following terms, on taking the Chair, for the first time, after his Election as President:—

GENTLEMEN,

I BEG to thank you for the honour you have done me, in electing me to the office of President of this Institution.

In undertaking the important duties it involves, I can safely promise not to fail in their discharge from any want of interest in your proceedings, nor from any lack of zeal for the advancement of the objects of the Institution.

The profession of which we are members has from my earliest days been an object of attachment to me, and were I actuated by no other motives, the love I bear it would prevent my becoming lukewarm to its interests. For my deficiencies, I trust to your forbearance, and rely on the help of the many friends I see around me.

It is important to notice at the outset, that the wide range of subjects which the profession of a Civil Engineer embraces, renders it imperative on every member of it to avail himself of all the help he can obtain. He requires the assistance of many departments of science and art, and must call into employment important branches of manufacture. He can perform no great work without the aid of a great variety of workmen, and it is on their strength and skill, as well as on his own scientific direction, that the perfection of his work will depend. The personal experience of one individual cannot fit him for the exigencies of a profession which is ever extending its range of subjects, and is constantly dealing with new and complex phenomena; phenomena, which are all the more difficult to deal with from the fact, that they are generally surrounded by such variable circumstances as to render them incapable of being submitted to precise measurement and calculation, or of being made amenable to the deductions of exact science. Consequently nothing is more certain than that he who wishes to reach the perfection of his art must avail himself of the experience of others, as well as of his own, and that he will not unfrequently find both little enough to guide him.

And let no inventive genius suppose that his own tendencies or capabilities relieve him from this necessity.

There is, I believe, no such thing as discovery and invention, in the sense which is sometimes attached to the words. Men do not suddenly discover new worlds, or invent new machines, or find new metals. Some indeed may be, and are, better fitted than others for such purposes, but the process of discovery is, and always has been, much the same. There is nothing really worth having that man has obtained that has not been the result of a combined and gradual process of investigation. A gifted individual comes across some old footmark, stumbles on a chain of previous research and inquiry. He meets, for instance, with a machine, the result of much previous labour; he modifies it, pulls it to pieces, constructs, and reconstructs it, and by further trial and experiment, he arrives at a long-sought-for result.

While, however, it is necessary, if our progress is to be safe, that we should proceed with due caution, it is exhilarating to notice, that in the matters to which our profession relates, progress is more apparent than it is in most other pursuits.

The great range of objects which it embraces, and which seems ever extending, partly, no doubt, accounts for this.

We are called upon to construct the great highways of nations, and to build the steam-boats that bridge the seas. We make the machines by which man seeks to lighten labour and accumulate force, or to give to that force new direction. We build docks, harbours, and lighthouses, to receive, shelter, and warn the mariner; and, as if in contrast to works so useful and so humane, some of us are occupied in the warlike objects of defence and destruction. And at this day, young Members can look back far enough to distinguish the rapid progress that has been made in those matters to which the Civil Engineer has to devote his attention.

Thus, it is hardly thirty years since travelling began to be transferred from common roads to railways. In the comparatively short period that has since elapsed, in a less space of time than one generation of man, about seventy thousand miles of railway have been made in different countries, at an outlay of about eleven hundred millions of pounds sterling, and involving an amount of engineering works exceeding in magnitude and importance all the previous engineering works of the world put together.

In effecting this great change, English Engineers have taken a prominent part, about one half of the vast outlay above referred to having been expended under their direction, and they may, I think, feel a pardonable pride in the great works which they have helped to construct, and which are destined to produce an amount of beneficial change and advancement in the habits and culture of mankind, which the most sanguine man of the present day will probably fail fully to estimate.

Simultaneously with this change and tending to the same ends, there has been the improvement of steam navigation. I crossed the Atlantic in 1835, in what was then considered one of the swiftest packets, but in those days the Atlantic packets depended wholly on sails, and the voyage occupied twenty days. Many years have not elapsed since it was denied that steamers could cross the Atlantic. They do so now in nine days. The progress that has been made in steam navigation in the last few years is truly remarkable. The steam-boats plying between Holyhead and Dublin, which were then, as now, among the fastest afloat, had, ten years ago, attained a speed of seventeen miles an hour. Last year those boats were superseded by others, the Leinster, Munster, Connaught, and Ulster, which attained on their trial trip a speed of twenty miles and a half an hour.

Great progress has also been made in the application of the screw-propeller to steam-ships, which, for vessels of war, and other purposes, possesses advantages over the paddle, though it has not hitherto accomplished an equal speed.

In 1848, the fastest screw line-of-battle ship in the navy could not steam more than about seven and a half knots, or eight miles and two-thirds per hour, whereas, the 'Warrior,' though clothed with an outer coat of iron armour four inches and a half thick, at her trial in October last over the measured mile in Stokes Bay, attained an average speed of 14·356 knots, or 16·533 miles per hour, beating the 'Howe,' which previously had attained the highest trial speed of any of Her Majesty's line-of-battle ships; the displacement, power, and speed of the two ships being as follows:—

Name.	Displacement.	Indicated Horse Power.	Speed per hour.	
			Knots.	Miles.
Warrior . .	8,852	5,469	14·356	16·533
Howe . . .	4,770	4,523	13·565	15·623

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Since 1848 the speed of this class of ships has been nearly doubled. The build and construction of steam-boats has also, during the same period, received much attention, and been greatly improved.

The doubts which prevailed until very lately, whether iron was the best material for line-of-battle ships, seem now nearly dispelled, although the rapidity with which iron fouls will, unless some remedy can be devised, be a source of trouble.

The precise and best mode of constructing iron ships of war is still an interesting problem; and many improvements may still be expected in an art which is yet in its infancy.

Hitherto a large amount of wood has been combined with the iron. The 'Warrior' has a thick lining of timber between the inner skin and the outer armour-plates. A material so soft as wood can hardly increase the capability to resist shot; and there seems great difficulty in combining, to any good purpose, two materials differing so much in strength and density. Besides which, wood rots, and is, in ships especially, a perishable material. The probability is that iron will supersede wood in a still greater degree, and that, by the adoption of improved modes of construction, the whole of the iron used in the structure of ships of war will be made to add to the strength of the ship, as well as be useful for its defence. This is not the case in the present mode of construction. The armour-plates of the 'Warrior' add very little to the strength of that ship. There seems to be no good reason why the upper and lower decks, and every portion of the hull of such vessels, should not be of iron. Greater strength would be thereby attained to resist diagonal and cross strains, and much greater longitudinal stiffness would be secured. Ships of war should be constructed practically, as far as it is possible, as if welded out of one piece of iron; and if they are ever to be used as rams, this mode must be adopted, for it is evident that the present methods of construction would be quite unsuited for such a purpose.

That war-steamers and other steam-ships can be made stronger, and may be made to steam faster than they yet have been, there is no doubt. No one can have taken the trouble to examine the present methods of building without seeing that it is easy to increase their strength without impairing their efficiency in other respects.

With regard to the speed we ought to obtain, it is with steamers as with locomotive engines, a question just now of what velocity we can afford to pay for, rather than of what rapidity we can physically attain. There is no doubt that the speed of either could be accelerated beyond any point yet reached, and probably beyond any point that the nation at present could afford.

The speed of steam-boats and of railroads will have to be determined from time to time, and will vary with circumstances, with place and time, with the accumulation and distribution of wealth.

For cost after all greatly, if not rigidly, regulates progress, whether it relate to civil, to military, or to naval affairs. A hundred years ago no nation could have afforded railways of fifty miles an hour, nor steam-boats of twenty miles an hour. The reasons for this are obvious, though often overlooked. Passengers, for instance, can afford a higher rate of speed than goods and minerals; and some descriptions of merchandize require to travel faster than stone, coals, &c. Again, some passengers can better afford to pay for speed than others. Even now it is on certain lines only that there are a sufficient number of passengers who are able to pay for express-trains, and where consequently the appointment of such trains can alone be justified. We have not yet, as respects steamers (except for short distances), secured an equal amount of passenger traffic; and until this be the case, they must be built and worked for passengers and cargo. Moreover, wherever time is an element of importance, the exigencies of trade and the convenience of the public require frequent opportunities of travelling and of transport from place to place. This circumstance determines the number of passengers and weight of goods to be conveyed each journey from each place, and, combined with other circumstances, establishes a law which for the time being regulates the load on every railway, in every steam-boat, and along each line of communication. Thus, large and powerful as locomotive engines have become, they convey on the London and North-Western and Great Northern Railways an average load of less than 70 tons of merchandize; and though the Lancashire and Yorkshire Railway has a larger mileage of merchandize traffic than either, the average load, owing to the close proximity of towns, and the greater necessity for frequent trains, is only about 45 tons. The same principle applies to steam-boat traffic. Again, however superior for naval warfare a steam line-of-battle ship may be to one with sails, yet England, rich as she is, could not at the present day undertake to support a navy which should wholly dispense with the use of sails, which should move to, and from, and among her distant dependencies by the power of steam alone, and which, consequently, would always be dependent upon, and therefore would always require to be supplied with a sufficiency of fuel.

With respect to the speed on railways, there is at present an anomaly, which, before long, will require more attention than at present has been bestowed upon it. Thus, to make way for passenger-trains, goods and mineral trains, which might move more slowly, are, in many cases, hurried on, manifestly to the prevention of due economy.

Besides, though I deem it possible that railways ultimately will be made for greater speeds than those at present adopted, I am of opinion that on some lines the Companies have attained a rate of travelling which is in advance of their appointments in other respects,—such as with the condition of their road, and with the state of their finances. Railway Companies already feel that great speed demands larger expenditure upon their permanent way—their rolling stock—for telegraphic signalling—and for other matters, without which the continuance of such speed becomes positively unsafe: and if the whole of the expenditure which great speed thus entails upon Companies were fairly met, it is questionable whether the present speed on railways is not, in many cases, fully greater than can be afforded.

Goods and minerals, on busy lines, are, there can be no doubt, carried at a speed which is neither demanded by the public nor is economical to the Company; but which is often rendered unavoidable from the necessity of keeping out of the way of swift passenger-trains, and by the difficulty of interpolating goods and mineral trains among the frequent trains of a large passenger traffic.

But is there no remedy for this? The travelling public demand from Railway Companies the highest rate of speed they can exact; and that, as I have observed, is sometimes greater than the state of the road and other matters warrant. Would any good result from the introduction of Government interference to regulate speed? I think not. Such a measure might strike at the root of improvement, and the evil is one which will work its own cure, and for which a remedy may be provided in different ways.

It has been urged that the time of travelling between two points may be shortened as well by diminishing stoppages as by an increase of speed. But this mode of dealing with it again becomes a question of cost; for if local traffic is not to be neglected, diminishing the number of stoppages involves more trains, more expense therefore, and the difficulty of applying this remedy will increase with the growth of traffic.

It may have to be met, in certain cases, by constructing lines to carry goods and minerals only, at a slow speed; and ultimately, perhaps, in other cases, at some future day, by making railways to carry passengers mainly, if not solely.

In grouping engineering works we may class the electric telegraph with railways and steam-boats. All three are agents of intercommunication, and tend to the same important ends. And while the vast importance of each cannot be overrated, the electric telegraph is, perhaps, in the peculiarity of its operation, the most wonderful of all.

It was about the same time that the Liverpool and Manchester

Railway was started that the minds of a few individuals were first devoted to the subject of using electricity as a medium of communication for messages.

Messrs. Cooke and Wheatstone's patents were taken out in 1837, but the first public telegraph was not established till 1839, when a communication was made by wire on the Great Western Railway between London and Slough.

Since that period, in this country alone, telegraphic communication has been extended over about 14,500 miles; in the rest of Europe, over about 100,000 miles; and in the American States, over about 48,000 miles; and the total extent of telegraph at this moment cannot be less than 200,000 miles.

On land, this most useful discovery has been uniformly successful. Like railways, it has grown (in England, by public support alone) into a great institution.

Ocean telegraphy has been less fortunate in its results. Short lines across the narrow seas have been laid and maintained, but at a serious cost.

To some extent, no doubt, the failure of deep-sea telegraphs may be attributed to ill-conceived arrangements, and to faulty designs and workmanship; but the very nature of such an undertaking as laying telegraph wires across the Atlantic precludes the possibility of acting on previously-acquired experience, and makes the requisite experimental trial one of serious cost.

The labours of the late Commission appointed to inquire into this subject have made the necessary scientific conditions for forming a good ocean cable better, and perhaps sufficiently understood. But they leave the ultimate cost of maintaining a permanent and available communication across three thousand miles of ocean (as, in fact, the great attendant contingencies compelled them to leave it) a question for the future to decide.

A communication with America once well established, would call for numerous wires. To meet contingencies, a single cable would not be sufficient. With ample provision in these respects, a communication between the two countries could be maintained, but at a cost not at present admitting of calculation. There are some things physically practicable, but which in a commercial and monetary sense are for a while unattainable, and the accomplishment of this great object may therefore be delayed. It is to be hoped, however, that it will not be abandoned.

Simultaneously with the rapid advance which has been made in the works to which I have referred, there has also been great progress in another branch of Engineering with which Civil Engineers have latterly become connected.

That new branch is gunnery. In a few years, mainly in consequence of the labours of Sir William Armstrong and of Mr. Whitworth, the range of artillery has been doubled. The weight of the gun in proportion to the projectile has been reduced to one-half, and the capacity for powder of the elongated as compared with the round shell has been more than doubled. This great advance in the destructive power of cannon has rendered most of our old fortifications useless. New fortifications have therefore to be built, adapted to the longer range and greater destructive power of the new artillery. These fortifications require to be placed more in advance of the places to be defended, and to be constructed with very superior powers of resistance to those which hitherto have proved sufficient. The old walled towns, which were formidable enough in former days, would to-day, in case of a siege, afford little security to the inhabitants; the old defences, therefore, have to be removed, and replaced by others more suitable to modern requirements.

We are clothing our ships of war in iron mail, and it seems probable that iron in some cases will be largely used in modern fortification. Not that earthwork and stonework will cease to be useful. These are the staple of most forts, but neither of them make good embrasures, and for that purpose iron offers great advantages. By its use greater strength can be secured at those points where power of resistance is specially wanted. By its use also the size, and consequently the exposure, of the embrasures will be diminished, and much greater facility be given for working the guns and training them through larger angles.

There are some cases, however, in which forts may with advantage be principally, if not wholly, built of iron. I hope to see that material adopted for the superstructure of the large sea-forts at Spithead, the construction of the foundations for which has been intrusted to me. There can, I think, be no insuperable difficulty in constructing iron forts so as to be impregnable to a ship's battery, though in the absence of knowledge as to what may be the ultimate powers of guns, it is not easy at present to arrive at safe conclusions. The difficulty of doing the converse of this, viz., of building ships so as to be impregnable to the fire of such artillery as may and ought to be placed in the new forts will be a problem not so easily solved.

No plated ship yet built could keep afloat under the fire of guns throwing shots of 200 to 300 lbs. weight; and it seems difficult, in the case of ships which require buoyancy, sufficiently to increase the thickness of their armour-plates to keep pace with the probable advance in weight and size of the new cannon.

Naval commanders rely a good deal, and perhaps up to a certain point correctly, on the mobility of their ships; but ships cannot be efficient if, to prevent being struck, they be always kept moving about. If never hit, they will of course receive no damage; but if ships are to resort to such manœuvres to avoid the enemy's fire, they do not seem adapted to bring great actions to a speedy conclusion. And how are such manœuvres to be managed with damaged rudders and disabled screws? Naval engagements will, in my opinion, be settled hereafter, much as they have been heretofore—the victory will be with the heaviest metal and the greatest daring. And after the various discussions that have been raised on this point, fixed and floating batteries will be found each to have their uses; and it is, I think, a limited view of the question that leads to an undue exaltation of one over the other. If land-batteries are, as some have urged, so innocuous to ships, why was Cronstadt not taken?

A very important question, viz., the use of iron for ships and forts, and war purposes generally, is now undergoing the investigation of a Committee specially appointed for the purpose, and it is to be hoped that their labours will lead to some important conclusions.

As respects the question of armour-plates, or of iron to be used for similar purposes, it would not seem that the hardest iron will prove the most suitable, unless it be combined with the greatest toughness. The force of impact is in a sense infinite. A ball cannot be arrested instanter in its flight. The thing struck, or the ball that strikes, must, one or both, possess some elasticity or ductility, or, if not, one or both must go to pieces. Of course the object to attain, as regards both ships and forts, is to devise a structure that will best arrest the shot and give strength to the structure; but we have not yet arrived at the best mode of doing this.

The use of iron is extending on every side. Its manufacture is also, I am glad to say, improving. There was great room for its improvement. Several processes for converting it largely into steel, or into a metal approaching steel in character, are also now in use, and promise to afford an article at a moderate price double the strength of ordinary iron. These discoveries will tend still further to extend the use of iron.

Should it turn out that steel, or homogeneous iron as it is sometimes termed, uniform in quality, and of double the strength of ordinary iron, can be manufactured in large quantities at a moderate price, and can be easily manipulated; then, many things that are now with difficulty accomplished will be greatly facilitated, and some things which cannot be done at all will be rendered practicable.

Bridges of greater span could be constructed. Screw shafts, crank-axles, and other parts of steam-engines, at present of unwieldy size, would by its use be reduced to moderate dimensions. There seems to be no limit to the size of guns, except strength of material, and the power of welding, forging, and handling them. Cannon, as we know, have already been greatly increased in power by adopting a superior material in their construction. Could we hit upon an inexpensive mode of doubling the strength of iron, the advantages to all sorts of machinery might be equal to those that would flow from the discovery of a new metal, more valuable than iron has hitherto been.

We are, I believe, in the infancy only of the manufacture of steel and iron. Until lately the nature of the demand for iron rather retarded than encouraged improvements in its manufacture. Railways consumed iron in vast quantity, and railway companies cared nothing about quality. They were driven to seek a tolerably good material for engine and carriage tyres, but as respected the vast consumption in the shape of rails, they were implicitly guided by the lowest prices. As long as this system continued, it suited the ironmasters to manufacture a cheap article in large quantities, and they therefore gave themselves no concern to establish a better state of things. But heavy engines, high speeds, and an enlarged traffic are gradually working a change. We are beginning to find that iron of the very best quality has hardly endurance enough for rails or locomotive tyres; that there is no economy in putting down rails which require taking up again in a year or two: and in short, that the increased strains arising from the accelerated motion of railways, steam-boats, and machinery generally, are necessitating a better material.

In marine steam-engines, which have received much attention, and where great attempts have been made at perfection, paddle-shafts, crank-axles, screws, and other portions have, as before intimated, already attained an unwieldy size, and the vis inertiæ and weight of such masses of metal are of themselves no slight impediment to the improvement of steam navigation, and would be greatly obviated by the use of a stronger material.

Fortunately for this country, just at the time that the use of iron is extending, and improvements in its manufacture are developing, fresh discoveries are made of the raw material, and men seem to stumble, as it were by accident, on new fields of iron ore, in places where those mineral riches have lain dormant for centuries, to await a new era and another age, when ships like knights of old are to go forth to battle in complete armour, and when the Civil Engineer has assumed the duties which devolved on the smith and armourer of former times.

Having noticed some of the advantages that may flow from a greatly improved quality of iron or a cheap manufacture of steel, or of a metal approaching steel in character, I may call attention to the great facilities that have arisen from the use of iron cylinders in sinking and securing foundations.

Before this invention, masonry built under water had to be performed by divers with helmets, or by means of diving-bells. That mode of construction does not admit of the best work. The stones are laid without mortar, and depend for their security on their large size, and on a good arrangement of bond.

It is true that concrete work (which however is inferior to masonry) could be built under water without either divers or diving-bells; by passing the concrete through the water to its destination in boxes or by means of shoots, and giving it the requisite form by casings of timber or iron.

This mode of building has long been adopted on the shores of the Mediterranean, and the docks and quay-walls at Genoa have been built in this manner.

But the use of iron cylinders not only admits of masonry or brickwork being built in mortar under water in any form, and with any bond, but enables the Engineer to excavate under water and to examine the ground before he begins to build, and to proceed with his work with as much deliberation, method, and security, and almost with as little delay, when 70 or 80 feet below the water level, as he can do on dry land.

Hitherto this method has been mainly confined to the use of circular cylinders, sometimes used (as was done by Mr. Brunel in the case of the Saltash bridge) as a means of building the requisite pier of subaqueous masonry, the iron being afterwards taken away, and sometimes to enable the requisite piers of concrete, brickwork and masonry to be executed, and by allowing the iron cylinders to remain afterwards to protect the interior work.

In other cases, the cylinders themselves are used to support the incumbent weight, and they then act simply as piles.

But it appears to me that this method of building may be extended with advantage much farther than it has been. It is adapted to almost any form of pier, and might in certain cases be usefully applied in building continuous walls, and I know of no system that is likely to afford greater help to the Engineer.

I have already said a few words on the progress of invention. This method of building is an illustration of the slow progress of really useful things.

In 1841 a patent was taken out for "improvements in the means of and in the apparatus for building and working under water;" and soon after the construction of the Rochester bridge, where cylinders were sunk under air-pressure, an action was brought against Messrs. Fox and Henderson, the contractors for the bridge, for an infringement of that patent. I happened to be engaged on that trial; and the fact was then brought to light that many years before, the late Earl Dundonald (then Lord Cochrane), had taken out a patent for a similar purpose very perfect in most of its details, for the drawings attached to Lord Cochrane's patent showed an air-lock almost identical with that now in use, and contained all the requisite arrangements for success. Lord Cochrane proposed to use it for overcoming difficulties similar to those encountered in the execution of such works as the Thames Tunnel; he proposed in fact to excavate such works under air-pressure.

This is another instance of the fertility of mind of that extraordinary man, who, great as he was as a Sailor, would probably have been equally eminent as an Engineer; and I here offer as a tribute to Lord Dundonald's memory this recognition of his early attempts to introduce the important system to which I have just been referring.

But we live in an age when men's minds turn to mechanical inquiries, and when probably they were never more fruitful in mechanical resources.

It is almost needless to give examples of this fact. The Locomotive Engine is a familiar instance, and Railway machinery generally affords many illustrations. The beautiful cotton-combing machine invented by Joshua Heilman, of Alsace, which was first used in the cotton manufactories to separate the fine from the coarse fibre, and has since been applied to wool, flax, and silk, and which acts almost with the delicacy of touch of the human fingers, is another illustration. Scheutz's calculating-machine is another remarkable instance, and many other cases might be named.

There is one subject, however, connected with mechanics which has hitherto been barren of result, about which men will occasionally occupy themselves, viz., the discovery of a new motive power.

The steam-engine, however, remains the only tame giant that is usefully subject to the will of man.

The little that has been done in the way of its improvement, since it left the hands of Watt, speaks volumes to the sagacity, industry, and untiring perseverance of that great man.

The late Mr. Kennedy, of Ardwick House, who was on intimate terms of personal friendship with Watt, on one of his last visits to Soho, asked him if he had discovered anything new in the steam-engine. "No," he replied, "I am devoting the remainder of my life to perfecting its details, and to ascertaining whether in any respect I am wrong." What the labours of that life produced we all know, and the patient concentration of will on his great object reminds one of Newton's similar labours in the perfection of his theory of gravitation, and evinces in the one case as in the other the truly great and philosophical mind, which is capable not only of discerning the dawnings of a great truth, and of appreciating its magnitude, but also of patiently pursuing its evidences until the whole is made clear as noon day.

At present it seems improbable, so long as motive power is to be obtained through the intervention of heat, and until a cheaper fuel than coal can be found, that the steam-engine will be superseded by any other machine.

Electric magnetic machines are perhaps the least likely of all inventions to supersede the steam-engine. The consumption of a grain of zinc, as Mr. Joule has shown, though much more costly than a grain of coal, does not produce more than about one-eighth of the same mechanical effect.

It would not, however, be at all safe to predict that considerable improvements may not yet be made in the steam-engine, or in engines to be worked by coal.

The consumption of fuel in the best steam-engines has been reduced to 2½ pounds of coals per horse-power per hour; but such an engine does not utilize one-fifth part of the absolute mechanical value of the coal consumed, and so long as this is the case, it would be unwise to assume that we have attained the utmost limits of improvement.

On another great branch of engineering, that of docks and harbours, I am not aware that much that is novel can be noticed.

The progress of such works is generally too slow to admit of much change in short periods of time.

An interesting discussion on the subject of harbours took place during a preceding session of this Institution. A considerable portion of that debate turned on the question of how far such works should be made permanent in the first instance, and how far they should be constructed so as to bring them into use with the greatest rapidity and at the smallest amount of cost, reckoning, of course, on rebuilding them at a future period.

This is one of those questions which it would be vain to discuss with any hope of coming to general conclusions.

In its naked form (apart from the question of harbours) it is one of the most simple and elementary questions. For it would not be difficult to show that if money alone be worthy of consideration, then, as respects public buildings of all sorts, the cheapest system would be to discard solidity and ornament, and to adopt structures of a more temporary character, the plan in fact which is always adopted in new countries.

But wealthy nations, like rich individuals, will spend more on themselves and also more on their public works and buildings than the absolute wants of a nation demand, and the fact is that men are not governed by monetary considerations only, but also by a sense of what is or is not appropriate.

We have however some exceptions to this rule. There are, for instance, the tattered and ragged margins of the Thames, where, in the greatest metropolis of the world, mud banks swelter and crazy buildings reel and totter against each other, but which it is proposed at a somewhat late hour to remedy.

Having thus touched upon the several points that occur to me as deserving of notice, I will conclude by remarking that no man can look back on the last twenty or thirty years without feeling that it has been the age of Engineers and Mechanicians. The profession to which we belong has in that period of time done much to change the aspect of human affairs; for what agency, during that period, single or combined, can be compared in its effects, or in its tendency towards the amelioration of the condition of mankind, with the establishment of railroads, the electric telegraph, and steam navigation?

For in constructing railways, telegraphs, and steam-boats, and their adjuncts docks and harbours, and moulding and fashioning the face of the material universe to the wants of man, in overcoming barriers, overleaping valleys, and spanning seas, Engineers annihilate both space and time, bring into juxtaposition nations and people, and accelerate, beyond all human expectation, personal communication, and that interchange of ideas which is all important to the advancement of civilization and knowledge.

Distance and separation have led and will always lead to misapprehension and prejudice—to ignorance and mistrust—to rebellion and war; and Engineers may feel, when labouring on the great public works that facilitate the intercourse of nations, that they are not merely conquering physical difficulties, but that they are also aiding a great moral and social work.

Being duly moved and seconded, it was resolved:—

> "That the President be requested to permit his Address to be printed and circulated with the Minutes of Proceedings."

The discussion upon the Paper, No. 1,046, "On the Discharge from Under-drainage, &c.," by Mr. Baily Denton was resumed, and occupied the remainder of the evening.

January 21, 1862,
JOHN HAWKSHAW, President,
in the Chair.

The discussion upon the Paper, No. 1046, "On the Discharge from Under-drainage, &c.," by Mr. Baily Denton was continued throughout the evening, to the exclusion of any other subject.

January 28, 1862.

JOHN HAWKSHAW, President, in the Chair.

No. 1,044.—"On the Form and Materials for Iron Plated Ships, and the points requiring attention in their Construction."[1] By JOSEPH D'AGUILAR SAMUDA, M. Inst. C.E.

IRON plated ships, having forcibly substituted themselves for the old wooden line-of-battle ships, have become a necessity. Such being the case, it is of great importance that this new mode of construction should extend and consolidate its advantages, and that those in authority should, for that purpose, avail themselves of the engineering skill of this country. The satisfactory solution of the problem would involve the necessity of obtaining; First, the best kind of construction of ship and armour, and Secondly, the best form and dimensions of vessel.

In the attainment of these objects, the following broad principles must always be kept in view, as indispensable conditions:—

1st. That these vessels should be constructed of such dimensions and of such power, and be built on such lines, as to command a superiority in speed over the best wooden frigates afloat.
2nd. That they should be protected by armour over the entire length of their top sides.
3rd. That the armour should be so constructed as to admit of rapid replacement, or of repair.
4th. That the armour should enter into the construction of the ship, and that it should be made use of, for the purpose of giving strength to the whole fabric, to carry its weight and bear its strain, as well as to protect the vessel from the fire of an enemy.

A review of what has been already done will show how far these conditions have been obtained, or are needed:—The 'Warrior' class of 6,000 tons, has obtained the speed, but has failed altogether in the other three conditions. The 'Defence' class, of 3,700 tons, has failed in all the conditions. The 'Valiant' class, of 4,000 tons, has partially approached the second condition, but fails, or will be found to fail, in the three others. The three new ships, of 6,700 tons, just commenced, if constructed as at present proposed, will probably possess the first and second conditions, but will fail as to the third and fourth.

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[1] The discussion upon this Paper extended over portions of six evenings, but an abstract of the whole is given consecutively.

It is now nearly three years since the 'Warrior' was commenced. The design, the mode of construction, and the specification for that vessel issued from the Admiralty. It is true that she is not deficient in strength, but without exception her construction is the most complicated and costly that was ever put together. The Author has on former occasions spoken in terms of high praise of this vessel as a first performance, nor does he wish to modify that opinion. The complicated construction might have been excused, if it had been confined to this one example; but as if blind to its imperfections, or wedded to its faults, the Admiralty have stereotyped its character, with scarcely an alteration, and in all their subsequent productions, have guarded it as jealously from change, as they protected the old wooden navy from the innovation of mail-clad iron vessels, until France was stated to have attained a dangerous advantage, and public clamour would no longer allow this country, to be left without the security, it had a right to demand, from a large addition of those formidable vessels to the Royal Navy.

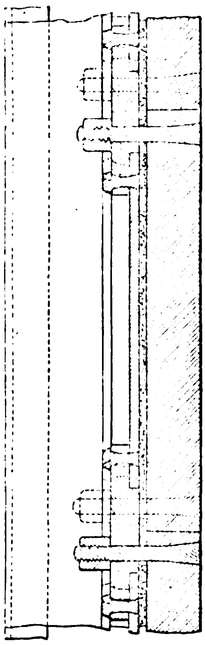
Instead of determining the governing principles, being guided by them, and at the same time encouraging all reasonable improvements in the details, the course followed by those in authority has had the effect of dealing with this important subject on the narrowest basis, and apparently on the assumption, that it was an absolute necessity, that the armour plates should be hung against the top sides of the vessel, which should be as like as possible to those of an old wooden ship. In point of fact, the matter has been dealt with as if it was not capable of improvement, or that it was not desirable to seek for it.

Many evils have naturally resulted from this ill-advised course. By accepting as a necessity, that the great weight of the armour was to be hung on, and the strain to be borne by, the top sides, the size of the vessel has had to be increased beyond what would otherwise have been sufficient, for the armament to be carried and the speed to be attained; and further, the armour has been limited to the midship portion only, in vessels of less than 6,700 tons burthen. This is the practical result of the treatment of the question by the Admiralty authorities. They have, by their acts, said to the country, "If you want a first-class frigate, wholly protected with armour, you must have one of the enormous size and expense of a vessel of 6,700 tons." And adhering to this view, they have accordingly contracted for three such vessels, at a cost, with engines, of about £400,000 each. This last conclusion has been arrived at, after no less than three classes of iron frigates, partially protected only, namely, the 'Warrior,' the 'Defence,' and the 'Valiant,' have been designed, or built. They appear to have become somewhat startled at the expense of a fleet of such frigates as the 'Warrior' and the 'Black Prince.' But instead of seeking a remedy in an improved mode of constructing the vessels, they built four more of decreased size, and these have failed altogether as regards speed, which was the only recommendation the 'Warrior' possessed to compensate for partial protection. In other words, after having been pressed to do something better than only partially to protect the future mail-clad navy, they have replied, by compelling the national purse to bear the heavy burthen already alluded to.

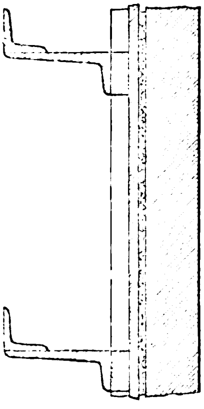
So much for what has hitherto been accomplished by Admiralty efforts. Dismissing these, the Author proposes to show, what could be effected by adhering to the conditions before referred to, as the basis of future operations. It is essential to cause the armour to enter into the construction of the ship, and be so made use of as to give strength to the whole fabric, as well as to protect the vessel from the fire of an enemy; and this being the foundation on which the other conditions depend, it is necessary to explain how it may be effected:—The framework of the hull is built as in an ordinary first-class steamer of similar size; no additional complication of any sort being needed. Outside the frames, and bolted, or riveted to them, are then attached five longitudinal ribs, reaching from the stem to the stern, at intervals of about 5 feet beneath each other; thus reaching over the whole of the portion of the top sides of the vessel, which is intended to be protected with armour, or about 20 feet from the gunwale downwards. These longitudinal ribs are formed of bars of rolled iron, 2½ inches in thickness, and 16 inches wide, the outer 4 inches on each side being recessed 1 inch, thus forming a section as shown in Fig. 1 (page 190).

The ordinary skin plates, 1 inch in thickness, are then fitted on and their longitudinal edges are riveted through the longitudinal ribs, where they are recessed. By this means a perfectly flat surface is formed over the top sides of the vessel, for the reception of the armour, which is then fitted on. Each strake is made to correspond with the pitch, or distance from centre to centre, of the longitudinal ribs; and the edges of the armour are bolted, or riveted through it, longitudinally; and the vertical butts of each plate, arranged to break joint with the butts of the skin plates, are riveted to corresponding ribs, 2½ inches thick, placed between the longitudinal ribs, and attached with fish-plates to them. This arrangement first makes a perfect ship without armour, and then allows a complete armour case, or additional skin to be worked outside, and attached through the longitudinal ribs, without interfering in any way with the joints, or fastenings of the ordinary skin of the vessel. The armour plating thus contributes, by its strength, to resist all strains brought on the sides of the vessel, by itself, or otherwise, to an extent equal to an additional skin of 2½ inches thick (the thickness of its butts) over the entire sides of the ship. So distinct is the ship from the armour, that in time of profound peace, the armour could be removed, and the vessel be used as an ordinary transport, if desired.

Fig. 1.



Vertical Section.



Horizontal Section.

The dimensions proposed are, for the armour plates, 5 inches thick, and for the longitudinal and vertical ribs behind them 2½ inches thick, with some slight reduction at the extremities of the vessel. The proportion between the armour plates and the supporting ribs, has been arrived at, from experiments made with the view of ascertaining what thickness of rib would be sufficient to render the edges of the armour plates, when weakened by rivet holes, equal in strength to the central body of the plate, where it is not drilled, or otherwise weakened. The Author found that half the thickness of the front plate exposed to fire accomplished this result. By this arrangement the desired object is attained of enabling the armour to be repaired rapidly, and at any point; and the strength which the armour gives the sides, reduces the question of protecting the vessel to its extremities, to a simple calculation of the sufficiency of the displacement of the hull. No necessity, or, rather, no excuse, exists for the tongueing and grooving of the plates which is used as an expedient by the Admiralty, to remedy the bending up at the edges, arising from the imperfect way of fastening, which is adopted in their mode of construction.

While the mode of tongueing and grooving has very imperfectly accomplished the object for which it was designed, it has induced the incalculable mischief, of preventing the possibility of taking out and replacing a broken plate, without removing the armour from a large portion of the side of the vessel. This difficulty exists in the 'Warrior' and her consorts, and the practical inconvenience that it entails has yet to be discovered.

From the preceding remarks it will be seen, that the plan of construction proposed accomplishes three of the indispensable conditions which have been previously laid down, namely:—protection over the entire length—an armour admitting of rapid replacement—and also entering into the construction of the vessel. The dimensions and power essential for securing speed remain to be shown. From a careful examination of all the points necessary to form a conclusion, the Author proposes, as the best dimensions for a 32-gun frigate constructed as described, a length of 382 feet, a beam of 55 feet, a depth of 31½ feet from the main deck, and a burthen of 5,600 tons. He also recommends that she should be fitted with engines of 1,200 H.P., and that she should be constructed on lines suitable to obtain a speed of 15 knots per hour with her armament, ammunition, and coal on board; and which, at the same time, would enable her to carry her port-cills 9 feet above the water-level. In other words, this frigate, of 5,600 tons burthen, would carry the same armament, and have even greater speed, than the 'Warrior' of 6,000 tons, while she would carry her port-cills the same height above the water, and have the invaluable addition of being protected over her entire length, with a more efficient armour than the 'Warrior,' which vessel has only 200 feet of her midship length, out of the total length of 380 feet, protected.

But the importance of an entire armour protection has now been recognised by the Admiralty, and has been adopted in their last contracts. Therefore it will be well to compare the advantages of this armour-skin vessel of 5,600 tons with those last ordered, and now building. The Admiralty vessels are 6,700 tons burthen, with engines of 1,250 H.P.; yet they are not to carry any greater armament, or have any greater speed, than the 5,600 tons armour-skin vessels. They will be less manageable, larger objects to fire at, and will cost £400,000. As the cost of the smaller vessel and engines will not exceed £340,000, a saving to the country of £60,000 would be effected in each vessel, which upon twenty-four cased frigates—the smallest number that Great Britain ought to be contented to obtain, at the earliest opportunity—will represent a saving of about £1,500,000 sterling in the navy estimates.

The Author's remarks apply thus far to first-class frigates only, those which, like the 'Mersey' and other similar vessels, were intended to keep the sea on foreign stations, to maintain the naval supremacy of the nation wherever required, and to act in the first line of battle. But in addition, a large navy, of a totally different class, is required for coast defences. Applying the same plan of construction, the Author would adopt for this fleet, vessels of the following dimensions and power: length 200 feet, beam 48½ feet, depth 25 feet, burthen 2,200 tons, engines 350 H.P. They should carry sixteen 68-pounder guns, but be pierced so that they could carry thirty-two. They would of course be protected from end to end, by plates varying from 4½ inches in thickness to 3¾ inches in thickness, and would have a draught of water of 16 feet, with guns, ammunition, and coal on board, and a speed of 11 knots. These efficient coast-defences, which might more properly be termed floating-batteries than frigates, would thus be brought within very reasonable dimensions, and would be both more efficient, and less expensive, than an extension of the permanent fixed fortifications, which the War-office authorities are desirous of carrying out.

It may probably be objected to what has been advanced, that the Admiralty are not prepared to abandon the wood backing. It could be shown, if necessary, that they are wrong in clinging to this issue; but as the Author's views on this subject, and the reasons that have induced him to form opinions unfavourable to wood backing are well known, and have been put forward on many occasions, it is not necessary to repeat them, or to enlarge upon them, in this Paper.

In conclusion, the Author thinks that the time has arrived, when the Admiralty should see the propriety, and the advantage which would result to the public service by abandoning the monopoly they have hitherto exercised, as it has restricted all advance in the construction of mail-clad vessels to such plans and systems as emanate from themselves; and that they should avail themselves of the assistance of the engineering skill of the country, and without warping it to their own views, leave it free to take the initiative, in improving this important branch of the national defences, they only exercising a veto to restrict it within such limits as their experience admirably fits them to form a correct judgment upon. In this way, the country would have the advantage of the competition of able and experienced Engineers, who for years have devoted themselves to this special branch of the profession; instead of, as at present, having to depend for these new and important structures, rising to an equal amount of perfection, while the development of their principles, and the organisation of their details, are left to the officers of the Controllers' Department, who must necessarily have a very limited experience in the engineering of iron floating structures. The Admiralty should bear in mind, that the time has not yet arrived, when the construction of one of these vessels can be proceeded with like that of a wooden frigate, building in one of the royal dockyards, where the experience of many centuries, and of all nations, as regards wooden vessels, is well known, and is most judiciously used to dictate every detail, with a tolerably certain conviction, that by pursuing that system a successful result will be attained.

The object of this Paper has been generally to point out, that the plan which has been adopted by the Admiralty is in danger of being accepted as an infallible rule for all future mail-clad ships, and that, by varying it, very considerable advantages may be obtained, and much expense saved. And the reasonable inference is, that the free discussion of this matter, and the proper encouragement of those members of the profession, who have applied themselves seriously to the subject, would develop other, and perhaps greater, improvements. The Author will have attained the object he has long desired, if he should be able to procure this advantage for the public service—this privilege and this just right for the Engineering profession.

This Paper is illustrated by two drawings, from which Fig. 1 has been compiled.

[Mr. J. D'A. Samuda

Mr. J. D'A. Samuda explained, that in the mode of construction he proposed, the skin was attached to the vessel in the ordinary manner, the only difference being, that when completed it would form a flush side, instead of presenting the series of overlapping joints which was usual in vessels of the ordinary build. The armour plates would be so attached to the vessel, that all the armour fastenings would be independent of the skin, joints, and ordinary fastenings. Between the armour and the skin of the vessel he proposed to put a packing of canvas and india-rubber, from $\frac{1}{8}$th of an inch, to $\frac{1}{4}$th of an inch in thickness, similar to that used in screwing up the joints of ordinary steam-pipes. This packing was not to produce elasticity, as that would defeat the object intended; but, on the contrary, it was used to produce a solid joint, which could not be attained with the rough surfaces of the plates as ordinarily made.

Mr. J. Ditchburn observed, through the Secretary, that in all the experiments he had witnessed, with heavy shot on armour plates, the fastenings of the plates to the ships' sides had invariably proved defective. Scarfs, overlappings, tongueing and grooving, or rebating, uniformly assisted the shot to damage the armour plates. There could be no doubt as to the practicability of efficiently securing the plates to the sides, without recurring to those sources of weakness. As regarded the size of ships of war, and the model upon which they ought to be constructed, he considered, that, however great their tonnage, when fully equipped for sea service, their draught of water should not exceed 25 feet; that their top sides should be inclined inwards from the fire of the enemy; and that their mid-ship body, under the water-line, should be so formed as to attain the greatest speed, and to counteract rolling, without the addition of bilge pieces.

Mr. Richard Roberts considered that in the construction of iron vessels of war, the armour plating should extend over the whole length of a ship, and that it should have as smooth a surface as possible. The method of tongueing one plate into another was open to serious objections. If a shot struck the plating at a joint, one-half of the tongued plating would certainly be split. A vessel also would require to be nearly stripped before a damaged plate could be replaced. The packing proposed by the Author was too thin. Packing of 2 inches in thickness would have been preferable, so that the rivets might have been completely buried. The necessity for trimming off the rivet heads would then have been obviated, and the strength of the vessel would have been increased. Iron vessels would be much stronger if they were constructed with two keels, which might be considered in the light of a couple of girders, extending from end to end of the vessel. Strong gunwales might also be added to correspond with them, so that the entire structure of the vessel would be similar to that of a beam. A vessel with two keels would have the further advantage, that if she grounded she would stand upright, and hence in time of action she would still be able to use her guns. A screw-propeller might be put at the end of each keel, but of a smaller size than that ordinarily used when a single propeller was employed. As the two screws would be more deeply immersed, the same, if not a greater, speed would be attained; and if constructed to act independently of each other, they would greatly facilitate the manœuvring of the vessel. They might also be so formed, that it would be impossible that they could be entangled by chains, or wreck. When steering the vessel by the screws, the steersman should be in the engine-room, and the orders should be conveyed to him in a similar manner to that adopted for conveying the orders to the engineer. Another improvement he would suggest, was, that the transverse beams of vessels should be made hollow. They could then be used for ventilating the ship, and in case of fire the steam could be turned into them, to aid in extinguishing it.

Mr. J. Scott Russell remarked, that the Admiralty, prior to building the vessels referred to in the Paper, invited six of the principal iron ship-building firms, including the Author and himself, to assist them with suggestions and advice, as to the construction of iron ships of war; at the same time reserving to themselves the power of examining the propositions, and of adopting such portions as they thought desirable; the object being to use the talent of the six selected ship-building firms for the benefit of the public. In his opinion the Admiralty had acted to the best of their knowledge and ability. The Author had justly praised the 'Warrior' as a first performance; and it must, therefore, be admitted, that the Admiralty took advice, used it, and, considering all the circumstances of the case, had been so far successful. No doubt the structural combination of the iron in the 'Warrior,' and in her sister ships, was more complicated than was necessary; and if some of the more simple arrangements of the iron, with which ship-builders were well acquainted, had been adopted, the same strength would have been obtained, with a less weight of iron; and it must be remembered, that with less weight of material, less size and greater speed would have been obtained. There were two principal systems for the construction of iron vessels at present known. One, the ordinary construction of numerous and close frames—a legacy from wooden ship-building, undesirable to be so closely followed; and the other, which might be styled the longitudinal system, where most of the iron used in the structure of the vessel was placed lengthwise, the transverse strength being mainly dependent upon whole, or partial bulkheads. Mr. Scott Russell had adopted the latter system ever since first he commenced ship-building. The Admiralty had adopted both these systems, in the vessels which they had constructed, and thereby the structural arrangement had become complicated, and too much material had been used.

In reference to the mode of construction put forward in the Paper, he had already expressed his opinion as regarded the desirability of dispensing with wood for backing; but at the same time he considered its continuance would be unavoidable, until the experimental trials at Shoeburyness had clearly demonstrated the superiority of iron. He agreed, as to the general principle, that the armour should enter into the construction of the ship, and be made use of to give strength to the whole fabric; but he did not think, that the system advanced in the Paper was that which was best calculated to attain those ends. The fastening proposed for the armour plating appeared to be its weak point; but as he had seen the most plausible theories dissipated by a single shot from a 100-pounder Armstrong gun, he only advanced that opinion for what it was worth. It was proposed, that the armour plating should be 5 inches in thickness; but he thought that a thickness of 4½ inches would have been sufficient. That thickness appeared to be indicated by the experiments with the Armstrong 100-pounder gun. All practical men knew, that in each material there was a certain thickness which would crack, but which would not bend, under the impact of a given force, and that there was another thickness which, under the same circumstances, would bend, but would not crack. The experiments he alluded to had shown, that the latter result was attained with a thickness of 4 inches, or 4½ inches, of good tough forged iron, but that a thickness of 5 inches, or 6 inches, of the same material, would crack before it would bend. If these views were correct, thinner plates might be used than those proposed by the Author, and the remaining material might be advantageously bestowed upon the actual structure of the vessel. Assuming that the wood backing could be dispensed with, which he hoped might be effected, he would prefer that the armour plates should be only 3 inches in thickness, and that the remaining 4 inches, or 5 inches of thickness, should enter into the solid structure of the vessel. Under present circumstances he, however, feared that such a disposition of the material could not be effected, but that a thickness of 4½ inches would be required for the armour plating, which, with the same weight, would only leave a thickness of 3½ inches of iron to put into the sides of the vessel. The problem therefore to be solved, was to build a vessel out of that amount of iron, in the strongest possible manner. As far as appeared at present, East India teak was believed to be the best material for backing. It was very desirable, that the armour plating should be made to give additional strength to the mechanical structure of the vessel, but he feared, that the system of fastening proposed by the Author would not answer the end intended, and that under fire from the 100-pounder Armstrong gun, or any equally destructive ordnance, the fastenings would soon be torn away, and the inner structure of the ship be exposed. No doubt, it was a difficult task to so arrange the fastenings of a series of 5-inch plates as to bind all the plates together, and at the same time to obtain the benefit of their additional strength in the structure of the vessel; but, on the other hand, it must be remembered, that more strength could be attained, when the armour plating was fastened upon iron, than upon wood.

The Author appeared to consider that small vessels could be constructed with shot-proof armour from end to end; but Mr. Scott Russell doubted the practicability of carrying out that idea, if the speed, efficiency, and sea-going qualities of those vessels were to be preserved; or unless the height of their ports, above the water-level, was so much reduced, as to render them incapable of fighting in a sea-way. It had been unanimously decided by a committee, composed of naval officers—who, it must be remembered, were the persons who would have to carry those vessels into action—that a ship would be useless for fighting in a sea-way, unless her ports were 8 feet, or 9 feet, out of water. The model exhibited by the Author, in illustration of his proposition, was that of a class of vessel similar to the old floating batteries. All practical men must agree, that those vessels could not be taken as examples, when sea-going qualities were required. If it was true that the ports ought to be 18 feet apart, and 9 feet above the water-level, and that a vessel of war ought to be coated to a depth of 5 feet beneath the water-line, then the armour on the side of the vessel ought not to be less than 21 feet in depth from its top to its bottom. A small vessel, loaded with that amount of armour, would be so deficient in sea-going qualities, that however cheap she might be, it would be undesirable that the lives and honour of British seamen should be risked on board of her. He would go farther, and say, that one good ship costing half a million sterling, was cheaper than two bad ships, each costing a quarter of a million. Now, that was the point where he found fault with the Admiralty. Having built the 'Warrior,' they found she cost nearly half a million sterling; and then they built two ships, intending that the two should be built for the same sum that the 'Warrior' had cost. The consequence had been, that the nation possessed two slow and bad ships, and that those two cost more money together than the one good ship. No one could object to the great cost of a ship which should be faster, stronger, possess more armour coating, carry more guns, and in every way be a better sea-going ship than her enemy. Such an investment of the public money would be a good one, and building a cheap ship could only prove a bad investment. The Author had assumed as an absolute necessity, that a vessel should be coated with armour through her entire length. No doubt it was desirable that, if possible, she should be so protected, but not if that protection deprived the vessel of her sea-going qualities. There were, however, circumstances in which small vessels were indispensable; and the practical solution of the problem was to give the greatest amount of protection to a small vessel, consistent with the preservation of her sea-going qualities. When Mr. Russell was consulted by the Admiralty, prior to the building of the 'Warrior,' he represented to the First Naval Lord, that the problem was a difficult one; the ship-building portion of it he would do his best to solve; but there remained what might be called the fighting portion, and upon that he asked, whether the Admiralty were prepared to sacrifice speed, and good sea-going qualities, to entire protection? or whether they would have a larger size of vessel, entirely protected, in which those points could at the same time be attained? or whether they would have a ship, with such an amount of protection as she could carry, consistently with the preservation of her sea-going qualities? The First Naval Lord, after carefully considering these questions with other naval officers, returned for an answer, that the vessel to be built must be of a certain size; that she must not have less than a certain speed; that the Admiralty would be content with a certain length of protection for her hull, engines, and a given quantity of her armament; but that they would not allow the vessel to be of the size, which Mr. Scott Russell had said would enable her to carry armour over her entire length, and would yet preserve her fighting and sea-going qualities. The plans were, therefore, sent in accordance with the stated limitations. The problem to be solved in the case of a small vessel was of a precisely similar character. Armour plating of 2 inches in thickness, although carried over her entire length, would be useless, as a shot would penetrate through it, and might strike her engines and boilers. If it was impracticable still to coat her from end to end with armour plates of 4½ inches in thickness, her vital parts should be protected with serviceable armour. Partial protection, in small vessels, was therefore an inevitable condition; and although he agreed with the Author in the desirability of carrying armour plating throughout the entire length of a ship, he must maintain, that the sea-going and fighting qualities of a vessel should never be sacrificed.

Mr. JOHN GRANTHAM considered, that the mode in which iron vessels should be plated to defend them from projectiles was a question, which must necessarily rest with the Admiralty, as it was only by direct experiment that the problem could be satisfactorily solved. It would, however, be well, where so large an expenditure was involved, that the Admiralty should carefully consider any representations which were made to them, by such scientific and practical men as had devoted their attention to the subject. It was the imperative duty of the Government to undertake the necessary experiments, for without those, no sure progress could be made. Why the experiments upon targets similar in construction to the sides of the 'Warrior' had not been made, until after that vessel had been built, was a question to which no satisfactory answer had hitherto been given. A series of experiments should have been made prior to her commencement. All properly qualified persons should have been allowed to be present at them, and all relevant suggestions should have been attended to. It was reasonable to suppose, that if that course had been pursued, the question, of the best mode of constructing armour-plated vessels of war, would long before the present time, have been satisfactorily solved. He believed, that the results of experiments, so carried out, would have clearly demonstrated, that iron was the best and, in fact, the sole material for the construction of vessels of war. It had already been proved to be the best for the construction of merchant vessels. Having given his close attention to the question of iron ship-building, for the last thirty-five years, he was not surprised at the opposition with which proposals for building vessels of war, entirely of iron, were met. There was the same hostility, when first iron merchant vessels were proposed. Experienced men said, an iron vessel was all very well in a river, or in a canal, but she would never do to go to sea, and that they might do very well when worked by steam-engines, but they would never do for sailing-ships. But let those who now thought in a similar manner, as regarded the construction of iron vessels of war, look at the great number of vessels which were actually afloat, and ask the leading shipowners of Liverpool and of the other principal ports of the kingdom their opinion of them. There were now scarcely any large vessels built for the Liverpool shipowners which were not built of iron; and even the decks of vessels were now being constructed of that material. The introduction of iron masts, yards, and rigging, and the substitution of chain for hemp cables had all been objected to in the same manner; but still the practical utility of iron had forced itself into notice. From his own experience, he was satisfied, that the time was not far distant, when there would not be another wooden vessel laid down to form part of the Navy.

Mr. Samuda explained, that since the Paper was written the question of adopting armour-plated vessels, entirely constructed of iron, had engaged the attention of the Admiralty. He was at present constructing a large target for the purpose of experimenting on the subject, at Shoeburyness. At the time he wrote the Paper, there was such an apparent confidence in wood backing, that he was glad to have now the opportunity of stating, that an alteration had taken place on that point, in the views entertained by those in authority.

Mr. G. H. Phipps considered, that the third and fourth of the conditions which were laid down in the Paper as indispensable, were, to a great extent, antagonistic to each other. It was impossible, that the armour plates could at the same time contribute to the strength of the structure, and yet be capable of rapid replacement, or repair, any more than a portion of the upper, or lower web of a girder could be made easily removable. It was also doubtful, whether any additional strength would be obtained by attaching the armour plates on the system proposed by the Author. There were two modes in which the strain on the sides of a ship might be regarded. Looking at the transverse section of the vessel, the sides above the water-line and between the decks might be regarded as curved columns, having to bear the superincumbent weight of the decks, together with their loading. Now, in consequence of the points of application of the top load being upon the inner edge of the vessel's sides, the tendency would always be to curve them outwards, and thus to take the pressure off the armour plates, rather than to put more pressure upon them. As regarded the longitudinal strain, a vessel was sometimes borne up by the water in the middle of her length, and, at other times, at her ends, and hence had to fulfil the conditions which were required from a girder, where the strain on the top, or the bottom alternated from a state of compression to one of tension. On that account, the leading iron ship-builders placed a considerable amount of iron longitudinally in the decks, and the other upper portions of the vessel. This literally formed the upper web of a girder, corresponding and balancing with the keel, skin, and other lower portions of the vessel, which collectively formed the lower web. If this view were taken of the structural arrangement of a vessel, it would be obvious, that a very small amount of tensile strain could be transmitted through armour plating fastened to a vessel's side in the manner proposed by the Author, in consequence of the impossibility of obtaining an adequate connection between the butt-ends of such very thick plates, similar to that obtained in the covering plates of a girder. Should it be urged that the connection might be made more complete, by increasing the number of bolts, he would reply, that in proportion as that was done, the third indispensable condition laid down in the Paper, namely, that of facility of repair and removal, would be departed from. As regarded the Admiralty, he would remark, that when Engineers and iron Ship-builders of undoubted experience and ability held opinions so opposed, as those which had been expressed, on the subject of the proper thickness for armour plates, it was unreasonable to require infallibility from a Board of non-professional men on that, or any other professional subject.

Mr. George Turner advocated the employment of British oak, Malabar teak, and the best iron, as the proper materials for the construction of the hulls of vessels of war. Exterior armour plating was necessary to defend the hull from the fire of the enemy. In his position of master shipwright of Woolwich Dockyard, he had naturally given much attention to the subject. His ideas as regarded the principles which should regulate the construction of vessels of war, would be best understood by an inspection of a model which he exhibited, and which he stated represented a frigate of the following dimensions, horse-power, and tonnage:—

Length, extreme	400 ft.	0 in.
„ between perpendiculars	370 „	0 „
„ of keel for tonnage	330 „	1 „
Breadth, extreme	64 „	6 „
„ for tonnage	63 „	11 „
„ moulded	62 „	7 „
Depth in hold	19 „	6 „
Draft forward	25 „	0 „
„ aft	26 „	0 „
Height of midship port above load line	10 „	0 „
Engines of	1,000 H. P.	
Weight of Hull	4,400 tons.	
„ Armour Plates	1,700 „	
„ Outfit	1,000 „	
„ Engines and Boilers	1,000 „	
„ Coal	1,200 „	
„ Reserve	263 „	
Total displacement	9,563 tons.	
Burthen	7,170 „	

The frame of the vessel was to be entirely solid, and of oak; the vertical joints were to be caulked inside and out; and the whole structure was to be bound together within the external planking by iron diagonal riders, so placed as to form squares with each other. In his opinion a vessel so formed of wood and iron would be much stronger than one constructed of wood alone. The casemated midship portion was proposed to be covered with two thicknesses of iron plates, the inside plates to be 2 inches in thickness, and the outside 4½ inches in thickness. The inside plates were to have a fastening which would be independent of the outside plates; but the fastening bolts of the outside plates were to pass through the inside plates and the sides of the ship. There would thus be a thickness of 2 feet 3 inches of wood, and a thickness of 6½ inches of iron, which would give a total thickness of 2 feet 9½ inches. The fore and aft portions were only to be covered with one layer of plate of 2 inches in thickness. The deck was also to be covered with a similar plating. Water-tight compartments were to be fitted inside the vessel. These were to be filled to just above the load-line with light tanks, the two lower tiers of which were to be filled with water, and the upper tiers were to be pressed full of cork chippings.

In answer to questions, Mr. Turner explained, that the communication between the compartments would not be entirely cut off. The model represented a vessel 5 feet 6 inches broader than the 'Warrior,' and 26 feet shorter. In fixing upon those dimensions he had in view the increased capacity required to enable the vessel to carry her armour plating. The casemated portion would form a battery of 250 feet in length, and the armament would consist of twelve 68-pounders and twelve of Sir W. Armstrong's 110-pounders.

Admiral Sir GEORGE SARTORIUS thought the Government had made a mistake, in not having given sufficient consideration to the fact, that the navies of the world were in a state of transition. The whole system of naval warfare had been changed by the experiments which had been made upon shot-proof batteries; and the number of vessels which had been sunk by steamers running into them, also proved, that a ship acting as a ram, could run down another ship, without being materially injured herself by the concussion. When the floating batteries were used in the Black Sea, two points were distinctly established: first, that wooden ships were useless when opposed to vessels which were comparatively invulnerable and incombustible; and, secondly, that if vessels were built of sufficient strength and speed to sink their opponents, they would be more formidable with their stems than with their guns. No ship could withstand their blow, nor could booms across a harbour resist their impact. He was at a loss to understand, why the English Government had built vessels of 6,000 tons to 7,000 tons burthen. In his younger days British seamen contrived to master their opponents, although the odds were two to one against them. He sincerely trusted that peace might long be preserved with France; but, as regarded naval matters, that country was the one which there was most reason to watch. Now, the war-vessels building in France were only of 3,000 tons, or 3,500 tons, burthen. Had British seamen degenerated that it had become necessary to reverse the proportions he had quoted? He firmly believed that they had not. The 'Warrior,' which had already been built, under the orders of the Admiralty, was deficient in some of the most material points that practical sailors of the present day considered essential for a war-vessel. The points he alluded to were, power and strength to overcome the enemy, pivot-like dexterity and handiness in manœuvring, and considerable speed. There were some descriptions of vessels in which speed must be the first desideratum, such as those employed in the protection of the national commerce, the destruction of that of the enemy, chasing a privateer, or running with despatches. But speed was not required for fighting the great battles which decided the fate of a war, for acting on an enemy's coast, for covering the landing of armies, or for protecting harbours, or coasts. Strength and power to overcome the enemy were the qualities principally needed in vessels of war, but in combination with pivot-like handiness to use them effectively. It must also be remembered, that in any future war the enemy might not avoid fighting, but would probably seek it. The vessel which had been built of 6,000 tons burthen carried only 26 protected guns. That was a most insufficient proportion of artillery to the tonnage. A vessel of the dimensions of the 'Warrior' required much too large a space to turn in, and much too great a depth of water to float in, to get sufficiently near when attacking a battery. While, on the other hand, from the deficiency of her qualities as a sailing-vessel, if she were within range of a battery, and her screw were disabled, she would never be able to get away, or to escape shipwreck, if on a lee-shore in a gale. The 'Warrior' only carried five days' or six days' fuel, and, except in the finest weather, and under the most favourable circumstances, she could neither tack nor wear, and even then she required 19 minutes of time, and 2 miles, or 2½ miles of space, to perform the latter manœuvre. Moreover, she steered badly, and when she took a sheer, no action of the helm could stop her. She was very leewardly, and rolled more than any ordinary line-of-battle ship. Although expressly built of sufficient strength to sink an opponent by concussion, a useless cut-water was added, which neutralized her power as a ram; and if she attempted to run down a vessel, her bowsprit and cut-water would be carried away, and probably her foremast would follow; so that, if she succeeded in sinking her enemy, she would, owing to the entanglement of the wreck of the two vessels, probably share the same fate herself; and, at the least, her screw would become fouled and useless. It had been asserted that, when an occasion arose, the carpenter's crew could soon knock away the cut-water, and render the vessel available as a ram. But let that alternative be fairly examined. It meant that ten men, or twelve men were to remove a mass of, at least, 20 tons weight, which was partly secured under water; and let it be remembered, that this operation would probably have to be performed when a ship was going into action, and possibly while she was under fire. In a dry dock it would take at least a couple of days, even if as many men were employed as could muster round the work; and when effected, owing to the shape of the cut-water, it was very questionable if the bowsprit, and consequently the foremast, could be properly secured. Against batteries, even if under perfect command as regarded taking up, or leaving, her position, such a vessel would prove a failure. Of what use could twelve guns, or thirteen guns be, when opposed even to a moderately strong battery, which would be armed with, at least, twice that number of equally heavy guns? Then, again, as the least motion of a vessel deranged the aim of the gunners, and rendered her fire uncertain, it could only be effective, even in comparatively smooth water, at a distance of 300 yards, or 400 yards. Such being the facts of the case, how could a vessel drawing as much water as the 'Warrior' approach near enough to a battery, to act efficiently against it?

The 'Warrior' would also labour under a serious disadvantage, when in chase, owing to her having no protected bow-guns. If her opponent had, like the 'Gloire,' five, or six stern-guns, and it was desirable to reply to their fire, she must sheer round her broadside, thus giving her enemy time to escape; or else she must continue the chase at the risk of exposing her unprotected points to the strongest of those of the enemy. If caught in a gale on a lee-shore, the 'Warrior,' to make head against it, must keep up her steam as long as the gale lasted; so that, even supposing her whole stock of fuel was intact at the commencement of the gale, it might be exhausted before its completion; her sails would be of no use to her in working off a lee-shore; and as she could not stay, and as each time she succeeded in wearing, she would lose 2 miles, or 2½ miles; there would be no resource but to allow the vessel to be wrecked. Surely every one of these defects, and many others which time would not permit him to notice, must have been known prior to the commencement of the vessel, to every practical seaman who had seen the drawings upon which she was proposed to be constructed. On the whole, he was of opinion that the plan of construction condemned in the Paper—namely, that on which the 'Defence' and the 'Resistance' had been built—was better than that which had been adopted for the 'Warrior.' Those vessels would be more effective, and would cost less money. The 'Defence,' were it not for her bowsprit, could sink the 'Warrior.' While the 'Warrior,' in consequence of the difficulty with which she manœuvred, could never run on board of the 'Defence' before the latter vessel had changed her position.

He considered that the only way by which the Government could arrive at a practical solution of the problem before the Institution, would be that of intrusting its examination to a committee composed of the principal wood and iron ship-builders, and of naval and artillery officers. As regarded the relative advantages and disadvantages of iron and wood; an iron vessel was much more liable to shipwreck than the ordinary wooden sailing-vessel fitted with a screw. It had repeatedly happened, that the false keels of timber-built ships had saved those vessels from total wreck; for, on losing her false keel, a timber-built vessel might at once float off; where, in every similar instance, an iron vessel would have been lost, on account of her having no false keel. The great improvements which were being made in artillery, rendered a corresponding alteration in naval architecture imperative. He believed, that guns would eventually be built, capable of throwing projectiles of 500 lbs., or 600 lbs. weight, and there was no iron plate which would be able to resist them. As regarded the arming of vessels, he thought there would be no difficulty in constructing vessels to carry 500-pounder, or 1,000-pounder guns. There was no reason why vessels of 1,500 tons burthen could not be built which would carry two, or three of those guns, and the vessel herself might be used as a gun-carriage, if they were always fired in a line with the keel. The guns might be built in the wood, and the recoil partially broken by buffer springs, as well as by the action of the vessel herself; the means for elevating, or depressing the guns might easily be contrived, and the horizontal pointing could be effected by the rudder, or by screws.

The Admiralty instructions for building the iron-plated war vessels referred to, had expressly stated, that they were to be "made strong enough to sink by concussion, and at the same time to be provided against the effects of collision." It was well known, that a blow with the beak of a vessel was more effective against an enemy than prolonged firing, and that the qualities necessary to secure the power of sinking by concussion, need not be attained by taking away any other quality, but that, in addition to possessing the power of acting as a ram, the battery of the vessel might remain quite as formidable. From the drawings which had been made by Admiral Elliot, of the different vessels of war now building in France, it appeared that they were all built with a beak at the bow, similar to that advocated by himself, and which he recommended to the Admiralty some years ago. The French had not, however, adopted his entire plan, which was to make the bow and stern alike, and equally efficient for concussion. There were numerous occasions when a vessel fitted with beaks at the stem, and at the stern, might occasion great havoc amongst an enemy's fleet, as, for instance, supposing a fleet to be lying at anchor at Spithead, Cherbourg, or Plymouth Sound, one of those vessels might run in and sink such vessels as the 'Warrior' and 'Black Prince,' while they were at anchor, or getting under weigh. It had been said that it was impossible for a vessel to give such blows without receiving injury; but Sir Edward Belcher had mentioned an instance of a vessel of 420 tons, which he commanded, running repeatedly against a mass of ice weighing about 59,000 tons. The vessel was successively run back, and then forward against the ice, at a velocity of 6 knots, or 7 knots, per hour, until it split and parted, but neither her masts, nor her engines suffered from the shocks. What, then, would be the effect of blows from a steam ram of 3,000 tons, or 4,000 tons burthen against a yielding object like a vessel afloat? The vessel assaulted would heel over, and her sides would be stove in, by a crushing, and not by a suddenly checked blow, so that those in the gunroom of the vessel which was acting a ram, would hardly be aware when a three-decker was sunk. He also believed that a vessel of 3,000 tons might be built as a steam ram, without any iron protection, for £150,000, and that such a vessel would be able to sink another, of the class of the 'Warrior,' if the attack was made at night, or when at anchor, or with her screw disabled. If shot of 500 lbs., or 600 lbs. weight were used, the armour plate would be of no avail, and what difference did it make whether the enemy's ships were destroyed by concussion, or by heavy shot? By either mode large unwieldy ships, like the 'Warrior,' could be destroyed by vessels of smaller size than themselves, while for general purposes smaller vessels would be far more useful. The tendency of the improvements which were being made in artillery, evidently pointed towards the necessity of having ships rather of moderate than of large tonnage.

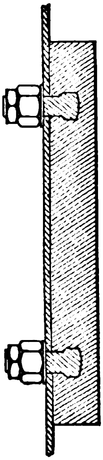
Mr. Sheilds said, it was an error to suppose, that there was any analogy between the vertical sides of an iron vessel and the horizontal flanges on the top, or bottom of a girder; but if the vertical sides of a ship, and the armour plates attached to them, were compared to the vertical web plates of a girder, the comparison would be correct. It did not appear to him, that the armour plates were in any way subject to tension, for even assuming the theory put forward in the Paper to be correct, namely, that they formed an integral part of the sides of the ship, the only good effect they could have would be to add stiffness to the construction. He, however, considered that, instead of adding to the strength, they tended to weaken the structure, by heavily loading it. Nevertheless, the plans by which the Author had provided for the disadvantages to which armour plates must in all cases subject a ship, were among the most efficient which had hitherto been proposed. The arrangement for attaching the heavy armour plates to a portion of the skin of the ship, specially made 2½ inches in thickness, for the purpose of receiving them, was a decided improvement upon the ordinary method of attaching them to a thin skin of only 1 inch in thickness, which was manifestly out of proportion to that of the plates, and comparatively insufficient for supporting them. It was obvious, that the plan proposed by the Author, allowed some degree of uniformity in relative size and strength between the skin plates, the armour plates, and the bolts, or fastenings which secured them to each other. It had been apprehended, that the heads of the bolts, by which the armour plates were fixed, would be knocked off by the blows of a shot coming against them. And in the elaborate experiments at Shoeburyness, the bolt-heads certainly did drop off in great numbers wherever the shot struck the plates; but as the Author proposed that bolts, or fastenings should be placed along all four sides of the plate, and as any three, or four of these bolts would be sufficient to hold the plate in its place, he believed the fastenings would be found to be practically sufficient. In fact, by the time that the fastenings along all four sides of the plate were knocked off, the plate itself would be demolished. It had been observed, that no matter how strong the armour plates might be made, the destructive power of the shot fired against them could be increased in greater ratio. The experiments at Shoeburyness had not, however, demonstrated that such was the case. Great improvements were being made in the manufacture of iron plates, and it was to be hoped that plates of 5 inches, and even of 6 inches, would hereafter be made with a much greater degree of inherent strength than at present. And as the strength of plates, which were otherwise uniform in structure, increased as the square of their thickness, it might be reasonably hoped, that the strength of the armour plates might be made to keep pace with any probable increase in the power of artillery. He approved of the system of vertical framing for ship-building, in preference to that of horizontal framing with bulk-heads, and recommended the adoption of a system of vertical frames, with inside horizontal frames attached to them at intervals of 6 feet, or 8 feet, over each other. By this arrangement there would be no necessity for bulk-heads, which had the effect of making a vessel rigid where the bulk-heads were placed, and weak in the intermediate portions. The system which he had recommended, on the contrary, tended to equalize the strength and rigidity of the vessel over the entire structure, and had the additional advantage of doing away with the division of a ship into compartments by bulk-heads; a clear space from end to end being a great desideratum in a merchant ship, for stowing cargo.

Mr. E. A. Cowper said, that in 1846 a number of experiments were made at Woolwich by order of the Government, on the effect of shot upon iron plates. A few of the plates experimented upon were 1 inch and 1½ inch in thickness, but the majority were only ½ inch or ⅝ inch in thickness. The ease with which the artillery of that period pierced through the plates, did much to retard the adoption of iron as a material for the construction of vessels of war, although the protection of vessels from shot by its means, had long been considered practicable by many eminent men. Some of the experiments were very remarkable, as showing that a much greater thickness of solid iron was required to resist the impact of shot. One of the shots passed through a coal-bunker made of plates of ⅝ inch in thickness, and containing 4 feet in thickness of coal, but the only effect of the coal and the two iron plates was to reduce the velocity of the shot. Another experiment was made with sixteen boiler plates, each of ½ an inch in thickness. These were riveted together, so as to give a total thickness of 8 inches. In that case, the shot also passed completely through, piercing one plate after another with little difficulty; and this simply because they did not form a mass of solid iron. The object to be attained was not that of lessening the momentum of a shot, as was attempted when protections of wood, coal, earthwork, &c., were used, but that of opposing a mass which, if it did not break up the shot, would at least resist it. A paving-stone, if thrown against a thin sheet of iron, such as was used to make a tea-tray, would probably destroy, or tear it, whilst the stone would remain comparatively uninjured. But if it were thrown down upon an anvil, it would most likely be broken to pieces. Precisely similar results ensued when a shot was fired against an armour plate. If the shot was not broken by the impact, it would go through the plate; but if the plate was heavy enough to present a resistance similar to that of an anvil, the projectile would be broken into pieces, and its fragments would be unable to penetrate the plate. It was obvious that the only portion of the plate which could be considered as an anvil, and against which the shot would be broken, would be that immediately around and at the point of impact. A plate would always have such an amount of elasticity, as to prevent its more distant parts from acting as an anvil, although, on the other hand, they acted as a tough support for holding the anvil in its place. In view of these principles, he could not agree in the mode of constructing armour plated vessels proposed by the Author. The division of the iron into several plates, and the fish plates behind the armour, were objectionable, and no advantage could be derived from packing of any kind; on the contrary, it would prevent the close contact of the inner and the outer iron plating. No one would think of making an anvil by riveting together a number of pieces.

As the edges of the armour plates were more liable to injury than any other part, it was desirable that the plates should be so connected together as to give additional strength to the vessel. To effect this, Mr. Cowper would propose that large square-headed screws, of about 6 inches in diameter, should be inserted in the joints of the plates, the thread being cut half into one plate and half into the other, so as to prevent any single plate being driven in; a contingency, which he maintained, could not possibly occur, unless the screws were cut in half, or the thread was completely stripped off. If the plates were made of sufficient length, and were so placed as to break joint with each other, the screw plugs which he recommended would have the further good effect of preventing the plates from sliding on each other lengthwise. The tension and compression could thus be continued throughout, and the plating on the side of the vessel, in its integrity, might then be considered as presenting similar conditions to the flat web of a girder, of the same depth as the armour plating. In addition to the strength which would be obtained by the adoption of the screw plugs, they would render the removal of a damaged plate a comparatively easy operation. To change a plate, it would only be necessary to take out the screw plugs, or if they were set fast, to drill them out, to fit the new plate in, and then to bore the holes, and to put new screw plugs in. A small portable engine, of about 3 H.P., might be used for boring the holes, and cutting the threads. The screw-bolts for fixing the plates to the ship could either be formed on the ends of the screw-plugs, or tapped into the plates, through about half of their thickness, from the inside, the heads being inside the skin of the vessel. The plan he proposed would render the joints nearly equal in strength to the centre portion of the plates. The system of grooving and tongueing was a source of much weakness, and rendered the plates liable to split at the joints, whenever a shot struck them near the edges. The bolts and screws, hitherto used in targets, had not been of sufficient size.

Mr. Brereton, having had some experience in riveting together large masses of iron, in situations where the workmen could not get at the heads of the rivets to hammer them up, had, under those circumstances, adopted a plan which he thought might be rendered available for attaching the armour plates to the sides of vessels of war; and on the appointment of the Government Iron Armour-plate Committee, he had suggested, that some experiments should be made to ascertain to what size of bolt it could be made applicable. The plan in question consisted in forming a countersunk dovetail hole, as shown on Fig. 2 (page 210), reaching half way through the plates, for the reception of the attachment bolt, which, when heated, was hammered in, and completely filled up the holes. The Committee authorized experiments to be made with bolts of 1½ inch diameter, and of 2 inches diameter, and he undertook a series of those experiments with different sizes and forms of countersunk holes. Doubts had been previously expressed, and it had been argued, that the attachment of the armour plates would be incomplete, owing to the imperfect filling-up of the countersunk holes, but the experiments showed, that in all cases, they were completely filled up. The Committee, however, notwithstanding the successful results of the experiments, had come to a conclusion unfavourable to the plan. It appeared, also, that they had been informed by some eminent ship-builders, that the system could not be used in some parts of a vessel. As it had been proved that the filling could be effectually accomplished, he considered that the only real test of the efficiency of his plan would have been, to have attached a plate to an iron target by the process he recommended, and by firing shot at it, to have ascertained whether that mode of fastening was stronger, or weaker than those which had been previously adopted, and which, it appeared, had been so generally condemned.

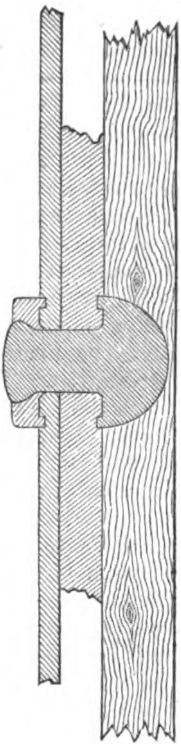
Fig. 2.



Vertical Section.

Mr. Gibbs considered, that the best mode of combining iron for the purpose of constructing a uniform defensive surface, would be that of crossing the iron plates at right angles to each other. If such a mode of construction was adopted, ribs, or stays would be unnecessary for sustaining the armour plating of a ship, or fort. The inner line of plates might be as thin as was considered desirable. The outer plates must of course be of the thickness required for defensive purposes. The method by which he would recommend that the iron should be put together so as to form the sides of a ship, or the face of a fort, was shown in Fig. 3 (page 211). The inner and outer line of plates should be fastened together by bolts and collars, which should be let into the front and back plates on the outside and inside respectively, so as to grasp the plates together. The shanks of the bolts were to be 6 inches in diameter. The combination he proposed would form a homogeneous mass of iron, which, without further bolting, or riveting, would be sufficient to resist the shock of a broadside, or the rolling motion of the sea. Although the heads of the bolts projected beyond the plates, it must be remembered that their size was proportionate to the size of the projectiles which would be likely to strike them. No doubt such projections would be a hindrance to a vessel's motion through the water, but the portion of the plating under the water-line might be covered with wood, as shown in the figure, recesses being left on the inside to receive the bolt-heads, while the outside of the wooden covering would present a continuous surface. Great facilities of construction, and much additional strength, would be obtained by making the vessel with upright, or wall sides, as far as the defensive portion extended. Ships of that form were not much admired, but the upright side need only extend to a depth of 4 feet, or 5 feet, below the water-line, and beneath that level a more approved shape might be adopted.

Fig. 3.



Vertical Section.

In the present state of naval warfare, steam power for steering vessels was almost a necessary auxiliary. Under ordinary circumstances, the steering of a vessel was dependent upon the rate at which she was passing through the water, so that large and heavily-laden vessels were liable to be out-manœuvred by lighter and faster vessels.

During the Russian war, he suggested to the Admiralty a mode by which a ship could be formed, with a shield across her, for defensive purposes. A vessel so equipped, could present her front to an opponent, and fire from a few heavy guns through port-holes pierced in the shield. All the parts of the vessel in front of the shield, and the shot-proof bulk-head connected with it, would be liable to be injured by a shot from the enemy, but a water-tight deck, placed a little below the load line, and extending only along the fore part of the ship, would prevent the vessel from becoming disabled. A steering apparatus independent of the rudder would be indispensable, on account of the necessity of keeping the shield at right angles to the line of fire of the opponent. The shield would swing on a heavy shaft, so as to lie down in the line of the deck during ordinary times, and would be raised to its defensive position by an hydraulic arrangement, worked by the same steam-engine which would be used to steer the ship. A number of these vessels might be placed side by side and connected, so as to form a range of battery of any extent, but yet be capable of changing the line of front according to any new position taken up by an enemy. He believed, that such a combination would be most efficient in guarding roadsteads and the entrances of navigable rivers and harbours. With regard to the heavy cut-waters which were proposed to be placed upon vessels, he believed there was an example of a Prussian steam-ship attempting to overtake a Danish sailing-brig and to run her down. Each vessel had peculiar advantages. The brig had a heavy battery, but no propelling power, while the steam-ship had the power of attaining great velocity. After a day's manœuvring, the steam-ship was not able to out-flank the brig so as to effect the purpose intended, because the brig always bore up, and presented her broadside just at the time the concussion was sought to be effected.

Sir JOHN DALRYMPLE HAY said, that he was glad to have an opportunity of defining the duties of the Iron Armour-plate Committee, of which he was chairman, as there seemed to be a general misapprehension on that subject. The Committee were only instructed to make investigations, as to the quality and description of iron which was best suited for defensive purposes, and incidentally, but not primarily, as to the modes of construction by which that iron might be made available, for the purposes of ship-building and fortification. The necessity for making the investigations with which the Committee was charged, had about a year previously become evident. The public was then called upon to spend large sums of money, for a new mode of protecting ships and fortifications with iron, and very little was known on the subject, even by the most experienced men. The results of the experiments in reference to the quality of iron had shown, that the softest description of iron—not the softer description of any other metal—was the best for defensive purposes. It was essential, that the iron should contain as small an amount of carbon as possible, that it should not partake, to any extent, of the character of steel, and that it should be extremely fibrous. It was at one time imagined, that the presence of phosphorus in iron was very deleterious, but from certain experiments, it was found that such was not the case; the fact being, that of all the chemical ingredients which were combined in iron, carbon was the most dangerous, when that metal was employed for defensive purposes. He would not now allude to the other chemical ingredients which it was desirable should be absent from iron, because the traces of them were very slight, and their effects were scarcely appreciable. The Committee had also ascertained, by experiments, the thickness and form of iron best calculated to resist the impact of a blow from a projectile. The results showed, that a thickness of 5 inches of iron gave the greatest protection in proportion to the weight employed. It had also been ascertained, with almost mathematical accuracy, that the resisting power of an iron plate increased approximately in the geometrical ratio of its thickness, or in other words, that sixteen plates of 1 inch in thickness united together mechanically by riveting, and not by welding, would only resist as much as one plate of solid iron of 4 inches in thickness. If, therefore, a plate of 1 inch in thickness was taken as the unit, it might be said, that a solid plate of 4 inches in thickness possessed a power of resistance of 16, a plate of 5 inches in thickness a power of resistance of 25, and so on. With the present amount of knowledge on the subject, he thought that it was not desirable to attempt to use armour plates of a greater thickness than 5½ inches. Beyond that thickness, the power of the machinery at present used in manufacturing the plates was insufficient, so that the iron was imperfectly united.

A variety of inventions of a very singular character had been brought before the Committee. Some persons, evidently considering that the protection of a ship from projectiles was a hydrostatic question, had proposed a thin iron casing, to be filled with water, and others had recommended a packing of hemp, and similar materials. The question of the best mode of fastening the armour plates was one of great importance. The Committee had ascertained, that if the plates were attached to the vessel's sides with bolts, a very good fastening was obtained. He did not say that it was the best, but he might safely state, that the public had not lost much money by that mode of fastening having been employed. Other means of fastening were occupying the attention of the Committee, and of the Admiralty, and he believed that a better system would ultimately be arrived at. Another point in which the public, having to make the outlay, was greatly interested, and which had received the studied attention of the Committee, was that of the necessity, or otherwise, for the wooden backing to the armour plates. There could be no doubt, but that the action and reaction of the iron and the wood, inducing oxidation in one and destroying the other, caused the structure of a vessel to deteriorate more rapidly than if the armour plates were directly secured to the iron skin of a ship. There were many reasons which rendered it extremely desirable that the ship should be constructed solely of iron; the experiments tending to make it probable, that the wooden element would be abandoned entirely. The experiments at Shoeburyness in November 1861, upon a target of the same section as the sides of the 'Warrior,' were of the most severe character. That target had a port, and was 20 feet long by 10 feet deep. It was fired at by the heaviest artillery of the old description, and at the greatest velocity, and also by the heaviest ordnance which Sir W. Armstrong had yet produced, and it stood the test remarkably well. At the same time, experiments were made upon four other descriptions of targets. One of these was composed of a plate 2½ inches in thickness, backed by a solid block of cast iron. Another was backed by a block of granite. A third was backed by oak bolted together;

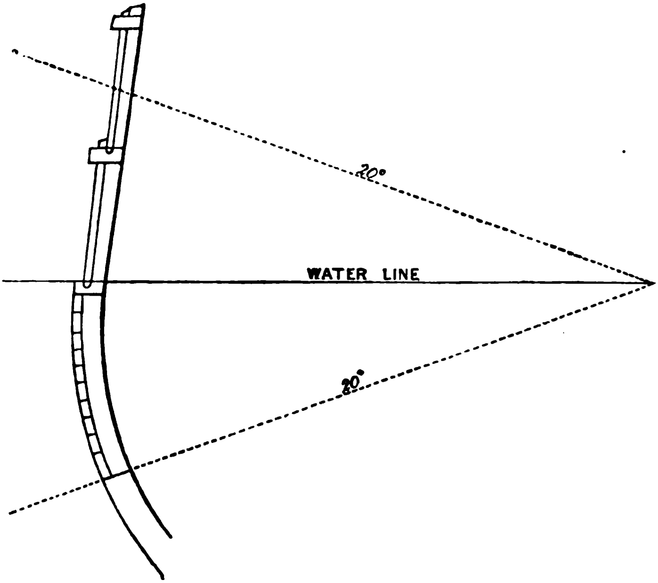
and a fourth by bitumen and cork, in order that the principle of deadening the concussion, or that of the buffer, might be tested. When these targets were fired at, it was found that the indentation made by the shot on the cast iron block was $\frac{6}{10}$ of an inch deep. Upon the granite block the indentation was slightly deeper, and the granite was also cracked and pulverized by the blow; whereas the cast iron, though split, was not displaced. In the case of the plate fastened upon oak timber, the shot penetrated the plate and destroyed it, making an aperture larger than the diameter of the shot, and penetrating 8 inches, or 10 inches into the oak. In the bitumen and cork a much larger hole was made. The experiments therefore proved, that the more rigid the plate, the greater was the power of its resistance to the projectile. When the bearing was rigid, the plate bent before it broke, but when it was not rigid, the plate was broken, or split, and was therefore destroyed. In the case of the 'Warrior' target, when oak was used for the backing, it was true that the plate was bent before it was penetrated; but, on the other hand, the oak backing proved so impervious, that the projectile never penetrated to the plate which represented the inner skin of the vessel. Since these experiments had been made, the Committee had caused another target, of the same size as the former, to be prepared, under the direction of Mr. Fairbairn, with a similar port, but without wood backing. The plates were a quarter of an inch thicker than those of the 'Warrior,' and rested upon a thicker skin, supported by iron ribs, but the total weight of the inner skin and ribs was less than in the 'Warrior' target. Experiments would shortly be made upon that target, to determine the extent to which the inner skin would be injured, by the shot impinging upon the outer armour of the structure. It was his impression that the inner rivets might be shaken out by the vibration; if such a result did take place, it would not prove that it was impossible to build a vessel entirely of iron, and would only go to show, that the system adopted, for putting armour plates upon wood, was not available for attaching them to the iron skin of a vessel. He hoped that the results of the intended experiments would be brought before the Institution, as well as the causes which had induced their success, or their failure.

Admiral Sir **Edward Belcher** did not consider it necessary that a vessel should be armour-plated throughout her entire length. Such an amount of protection as would shelter the machinery from injury and render the vessel unsinkable would be sufficient. For the other parts, an adaptation of strong, yet moveable defences, to cover the guns and the men who worked them, similar in extent to that given to artillerymen in the field, was all that was essential. He did not concur in the opinion, that the armour should enter into the construction of the ship, but on the contrary, he considered that the structure of the ship should furnish aid to the armour. The wooden timbers formerly used, should be replaced by iron ribs of from 12 inches to 15 inches in depth, and of a wedge shape, 2 inches wide outside, to 1 inch wide inside, and so far asunder, as to act with the outer plates in preventing a shot from passing, or in other words, just the diameter of that shot which would perforate plates of 4½ inches in thickness. It was possible, that an interval of 8 inches would answer the purpose, as it might be assumed, that no perforating bolt could pass entirely through the armour-plating, and it was certain that no shell could.

As regarded the question of speed, he could not agree with those who placed that quality last in order of importance. In his judgment speed in a vessel of war was preferable to armament. It was a matter of great moment that the armour-plating should be so fixed as to be capable of rapid removal. If one of the armour-plated vessels was found to be hampered at sea by her armour, or if she was aground, and required to be lightened, the armour plates, as at present fastened on, could not be hoisted inboard, or cast overboard. Although it was stated in the Paper, that the vessel might be relieved of her armour and used as a transport, he considered it impossible to meet the emergencies to which he had alluded, by the system of fastening proposed by the Author, or indeed, by any other which he had heard described, or of which he had seen plans, or models. The expensive modes of construction, the multiplicity of fastenings, the increased weight and labour required to extract the bolts, or screws, the necessity for the employment of skilled workmen, and that the vessel should be in smooth water, and in a state of repose, were all serious objections. The requirements of seamen were, a mode of disconnection at which they alone need be employed, and equal facility of replacement. The great size of the plates prevented them from being easily handled, and a further difficulty arose from their being applied longitudinally to the sides of the vessel. He, however, admitted that it would be difficult to apply them in any other manner without impairing the form and smoothness of the vessel, and thereby lessening her speed.

In the construction of vessels of war, Sir Edward Belcher would recommend, that an entirely new system should be adopted for fixing the armour plates. The longitudinal girder stringers, ordinarily used by ship-builders, should be placed at certain specified levels, one of which should be at the water-line, as shown in Fig. 4 (page 216), which represented a portion of the side of a frigate. Below the water-line the vessel should be plated in the usual manner with longitudinal plates, to such a depth as would be exposed when she rolled about 20°. This in a frigate would be about 12 feet. The portions of the vessel's side above the

Fig. 4.



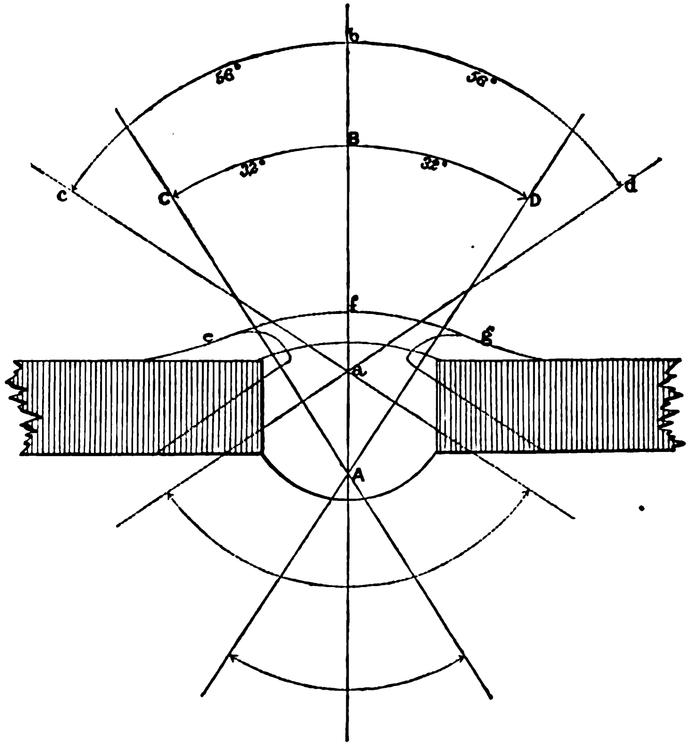
Vertical Section.

water level would thus be free from top hamper, and with the exception of the addition of the longitudinal girder stringers, she could then be completed, and tried as an unplated vessel. The next longitudinal girder stringer should be placed at 7 feet above the water-line girder, and if required, it might be ornamented. The upper girder should be placed at a similar distance above. All the longitudinal girders should be well secured to the main framework of the vessel, of which in effect they should constitute a part. The moveable armour plates, of which he had previously suggested the adoption, were to be made in short lengths not exceeding 12 inches in breadth. Their ends were to rest on the girders, and the upper shoulders were to be confined to the sides within the stringer bands, and when securely fitted, keyed, and caulked in, they would not only present the same opposition to shot, as the armour at present constructed, but the want of rigidity caused by the bolts would prove an advantage, as presenting an elasticity, not found in the solid bolted plates now in use. A vessel so fitted might also quit this country without her upper and second courses of plating, and in the event of war, might, under the directions of the Engineer and ship's artificers, be completed for service by the crew alone. The 'Warrior,' owing to her draft of water, might be considered as a sea frigate, and not as a harbour battery, but the system of armour-plating which he had described would be available for harbour operations. In the still waters of India and China, batteries 'à-fleur-d'eau' might be rapidly constructed by removing the plates; and by using similar hanging plates at the water line, timber vessels of light draft of water, or even rafts, might speedily be converted into armour-plated floating batteries.

The smooth straight sides, which had been adopted in constructing armour-plated vessels, had comparatively destroyed the facilities for the fore-and-aft training of the guns, to the acute angles which were afforded by the old curved forms of a vessel's side. When the 'Warrior' was launched, as it appeared that the angles to which her guns could be trained were limited to 32° forward and 32° aft, Sir Edward Belcher wrote to the Admiralty, suggesting certain alterations in the pivoting of the guns, and in the shape of the port-holes, which would have had the effect of increasing the angular range to 56° forward and 56° aft. His recommendations upon this point would be best understood by a reference to Fig. 5 (page 218.) When the vessel was originally fitted, the gun-carriages were pivoted, or centred upon the inner skin of the vessel at **A**, and the range was limited by the sides of the ports, as shown by the continuous black lines, to the arcs **C B**, and **B D**. Instead of that arrangement, he proposed, that the gun-carriages should be centred on the outer skin at *a*, and that the interior portion of the sides of the port should be cut away to the dotted lines on each side; by these means the gun would have ranged through the larger arcs *c b* and *b d*. To afford additional protection to the men working the guns, he proposed curved wrought-iron port frames of double thickness. The reply he received from the Admiralty was, "that the difficulty had in part been met by reducing the aperture," but he believed, that the main objection to the adoption of a plan which would have greatly increased the efficiency of the vessel was the real, or supposed unsightliness, of the series of carbuncular projections along the sides of the vessel, which it might have been thought would have spoiled the otherwise symmetrical appearance of the vessel. He had, however, seen such a plan successfully adopted in old ships of the line and frigates, fifty years ago.

As regarded the question of sinking the vessel of an enemy by concussion, Sir Edward Belcher had had some experience in charging floe ice. The shock received by a vessel running into the ice was such, that he was led to infer, that if a stubborn resisting body had been substituted, considerable damage would have been inflicted upon the vessel charging it. If a vessel received a very severe shock in charging another, her machinery and standards would be so far injured, as to prevent her repeating the blow, so that really such a mode of attack would be risking all on the chance of success. The inwardly-inclined, or 'tumble-in' cut-water and bow, which had been proposed for the steam rams, would be likely to force them underneath their opponents; whereas, the old overhanging shape of cut-water and bow gave a vessel a great advantage in charging another, as it would cause her whole weight to be forced on the top of her opponent to override and submerge her.

Fig. 5.



Horizontal Section of a Port-hole.

The question of the amount of armour which a vessel could bear had frequently been discussed, and those acquainted with the subject were justly nervous, when it was proposed to increase the weight in a vessel by a few hundred tons. But while fixing upon the form for a vessel's bow and cut-water, it would be well to contemplate the imposition of the weight of the 'Warrior' upon an overburthened iron-clad vessel. If that weight—9,000 tons—impelled at a velocity of 10 knots per hour, merely rested upon one of her extremities, where would her adversary be? Another reason why the high and commanding bow should be retained, was that it afforded a position from which the enemy's decks could be overlooked, and boarded, while that form of bow itself was adverse to any similar attempt which might be made by the enemy.

The question as to whether, or not, a vessel of war should be plated with armour throughout her entire length, was one upon which some hesitation was necessary. He considered that the waist of a vessel should be shot proof for a certain distance both above and below the water-line. By means of the system of armour plating which he had recommended, having completed a vessel without the upper courses of plating, he would allow necessity alone to be the guide, caring little for holes which did not touch a vital part, and which could be repaired at leisure.

As regarded the Admiralty, without proposing to appear as their champion, he would remark that they might possibly entertain the idea, that if they could build, they could also repair their vessels. The execution of the repairs was an important question, and one involving a large expenditure. Again, the Admiralty might imagine, that if they built the armour-plated vessels, they might possibly ascertain their actual cost, and hence save the commission on the expenditure. On all sides they were beset by complaints against the favourite of the iron-ship builders, the 'Warrior,' and as they had determined to try the experiment, although he did not contemplate they would obtain any great results, yet in the interest of the public he heartily wished them success.

Admiral FITZ-ROY considered, that to render conclusive the valuable investigations of the Iron Armour-plate Committee, experiments should have been made, to ascertain the effect which would result from projectiles fired at a series of successive plates, three, or more in number, say of 1 inch, 1½ inch, or 2 inches in thickness, at varying distances and intervals apart. As far as he understood, in the experiments which had been made, a shot had been fired against several thicknesses of metal placed close together, they might possibly have been rolled together, but they did not form one solid homogeneous mass. Now he contended, that the conditions of a mass of iron 5 inches in thickness, formed into one truly homogeneous mass, under a Nasmyth's hammer, was different to that of an equal thickness of metal placed together, layer by layer, and merely rolled, or otherwise superficially united. To take an extreme case, the difference might be illustrated by comparing the one to so many sheets of paper, so placed as to touch each other, but no one of which, although in close juxtaposition, was immediately connected with the others: and the other to a sheet of cardboard, or papier mâché, which was intimately and fibrously connected, as a solid substance, from one side to the other. The impact of a shot striking a solid mass of iron was felt quite through the mass and to the back of it. The shot could not penetrate the smallest fraction into that mass, nor could it cause any dent on the outside of the plate, without effecting a corresponding result on the back, or furthest side of that mass. Supposing that the iron possessed only a very small degree of elasticity, or yielding compressibility, if not pierced through, there might be an indentation to a certain distance, but the force of the impact would be felt entirely through the iron. If one hundred steel musket-balls were placed in a line close together, and confined, laterally, and the one at the end was touched, the same amount of impact would be given to the furthest ball in the line, or tube. Upon the same principle, the force exerted upon a solid mass was not to be measured, or estimated so satisfactorily by comparison of the effect of that force upon successive and contiguous layers, as by a variety of trials against equal, or other thicknesses of metal more, or less separated. If, when making the experiments, the plates of iron, instead of having been placed side to side, and united to one another, had been placed at certain distances, say, at 3 inches, 4 inches, 6 inches, 12 inches, or even more apart, the force would have been diminished in passing through the first plate, and it would not have acted upon the second plate with its primary momentum. Supposing that the shot had actually struck directly at right angles to the first plate, it was probable that it would be more, or less deflected before it reached the second, and the second and succeeding plates would deflect it still more. A shot striking a series of plates, so placed at intervals apart, would not only be deflected, but in many cases it would be broken. The thickness of the sides of the 'Warrior' being about 3 feet, a succession of such 'shot plates,' might be placed within that distance, and the projectiles which passed through the outer plates would probably be deflected, so that they would merely fall between the spaces without penetrating the inner plating, or skin of the ship. It appeared that some experiments were about to be made at Portsmouth, with the object of ascertaining the extent to which a shot passing through a comparatively small thickness of iron, say of 1½ inch, would be checked and deflected. The result of those experiments would, no doubt, to some extent, show the correctness, or otherwise, of his views.

In a letter which he had written on this subject in April 1861, and which had been published in the 'Shipping and Mercantile Gazette,' he had expressed the opinion that any degree of tenacity, ductibility, or toughness, could be procured by working good iron properly; and if successive plates, one within, or behind another, either contiguous, or separated by moderate spaces, with abundance of angle iron, or ribs in every direction, were substituted for clumsy, unmanageable, and very unreliable thick plates, any degree of strength, any amount of gradual resistance, equivalent to that of wood, and any check to the inward flight of splinters, might be obtained. He had also recommended that the tubular, or cellular principle—that of bridges, built beams, or girders—should be adopted extensively, the number of plates being increased, at various distances, so as to ensure strength, good work, and good iron. By the tubular, or cellular principle, he, of course, implied that structure which the late Mr. Robert Stephenson adopted in the Britannia Bridge, and which, to a great extent, the late Mr. Brunel had employed in constructing the 'Great Eastern' steam ship. An outer covering, or skin, separated from, but connected with, an inner coat, or lining, was, in fact, an inner case. The separate, continuous, and water-tight platings might be a few inches, or a few feet apart, according to the vessel's size. In a large ship-of-war they might be about 3 feet apart, and have an intermediate similar case, of tough plate iron. Between these skins any number of plates could be introduced, a few feet in length, about 1 foot wide, and perhaps of iron ½ inch in thickness. These would slide into, be suspended edgewise by, and be keyed to the ribs of angle iron, or their substitutes, namely, transverse plates of iron bolted to both the inner and the outer cases. All these plates might be similar; every hole, tenon, and key, every bolt and rivet alike, in sets, or sizes, for each class of ships. When not preparing for defence, a ship so fitted might displace her shot plates (which would be only from about the water-line to the upper bulwark) and stow them below. The lower part of such a ship, from about 2 feet below the water line, need not have any such plates, but a third skin, and additional diagonal angle irons as sleepers, trusses, or ribs. Strength should be obtained by placing plates of iron edgewise, multiplying, combining, and connecting, while separating them; not by unwieldy masses of uncertain nature within, which would not expand, or contract equally with thinner and less inflexible metal.

If a shot struck a solid mass, every atom in its line of force was impinged upon almost equally; but the impact on a plate within, or behind, not a part of the mass first struck, was much less, and proportionally for any number. The iron ships that had been broken through by shot, or by rocks, except the 'Great Eastern,' had no such second, much less third, or fourth skin. Combinations of wood and iron were well known to be objectionable, theoretically and practically.

In war, vessels constructed of wood alone, were mere fuel for modern incendiarism. Iron ships required to be coated with a preparation, which would preserve the metal and poison marine parasites. If such a coating was applied once a year, it was sufficient. Internally, vessels required abundant ventilation, on account of moisture being deposited when sudden and considerable changes of temperature occurred. They also required pannel linings for cabins and other wooden coverings, all light and moveable. Iron masts and yards had already been made tubular, and sufficiently jointed. Iron rigging had long been in use.

An important point to be kept in view on board long iron ships, was the expansion and contraction of the iron, as it affected the fixings of the engines, which were comparatively permanent; but that point only required to be mentioned, as the remedy was well known to Engineers. Much remained to be done by using iron that did not corrode, by the application of a thin sheathing of galvanised iron, as copper was used on wood, or by aluminium, or by electro-plating the pieces used in water. But on the whole, iron ship-building could no longer be considered experimental, and he felt convinced that there was nothing attainable in a wooden ship that might not be better effected by the use of iron, or some other metal. The practice of fixing extra armour plates to the sides of an iron vessel was grounded upon an erroneous idea. When Engineers and Ship-builders were called upon some years ago to protect the sides of wooden ships with iron, it was indispensable to devise the best means of uniting such plates to their sides Further experience had, however, shown that it was a mistake to put iron plates upon wooden ships, and that the two substances were so much at variance, as never to work together properly on the side of a vessel. When it became necessary to build iron ships of war which would be shot-proof, the whole question should have been reconsidered, instead of following the old beaten track, which was pursued by those who were only accustomed to put armour plates on wood. At present large masses of iron were proposed to be bolted to the iron ships of war. Surely that iron being of a certain weight and strength, should, while affording protection against shot, be so disposed as to add strength to the whole frame of the vessel. No doubt, if the Admiralty, or any public body having the power of the purse, was to say to Engineers and Ship-builders, "We want the best ship you can give us. She must possess certain qualities, build her according to your own views," a ship of iron would be constructed, with no iron wasted, no weight thrown away, or injuriously applied, and no part stronger than the weakest part. It was a well-known principle, that however much one part of a ship might be strengthened, it would not add strength elsewhere, and that the strength of any structure was measured by the strength of its weakest part. At present the iron war vessels were strong in some parts, while weak in others. Such a mode of construction should not have been authorized, and ought not to be continued.

The 'Warrior' had peculiar defects, and it was desirable that they should be pointed out, before another vessel of that class was constructed. Her ports were so narrow, that if, in an emergency it were necessary to cast her guns overboard, that operation could only be performed with extreme difficulty. Protection for the crew who fought the guns was not so indispensably required, as on that account to exclude other, and possibly more important requirements. Proper provision should be made for ventilation, for the easy working of the guns, and for the guns being cast overboard, or hoisted in-board through the ports. There were occasions, when it might be indispensable that the guns should be got on board through the ports, instead of by the hatchways. The method by which the armour plates of the 'Warrior' were united to the fabric of the vessel, which rendered it impossible to remove a plate needing repair, without taking a large part of the vessel's side to pieces, was one which required revision in other ships.

Sir JOHN HAY explained, that in the experiments about to be made at Portsmouth, it was proposed to place two iron plates of $\frac{5}{8}$ths of an inch in thickness at a distance of 15 inches apart. These plates were to be attached to the side of the 'Java.' They were then to be fired at, to ascertain whether the momentum of the shot would be lessened in passing through the outer plate, and if so, whether it would retain sufficient force to break the inner plate. He would not detain the Meeting by entering into the scientific reasons, which induced other members of the Iron Armour-plate Committee, as well as himself, to entertain the opinion, that the fracture of the outer plate would not absorb the momentum of the shot, or prevent its conveying the force, derived from the explosion of the powder, to the second plate. The shot must be viewed as a connecting link, between the original explosive force of the powder, and the remaining momentum arriving at another object, which object must absorb that momentum, or must suffer. Unless the second plate was of sufficient thickness to absorb the momentum, it would certainly be injured; and such he believed would be the practical solution of the question which would result from the experiments.

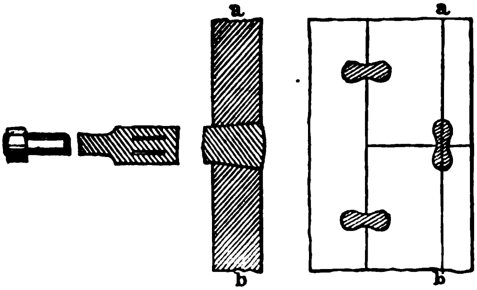
Mr. FAIRBAIRN said, that the investigations he had made on this subject, had convinced him, that the principles of constructing iron ships, heretofore adopted, were radically imperfect. If an iron vessel was treated as a tubular girder, by resting her weight on her bow and her stern, and leaving the intermediate portion unsupported, it would be found that there was not a sufficient amount of material in the upper deck to resist compression and to support the vessel in that position. The law of the balance of the two forces of compression and tension appeared to have been generally neglected, and with the exception of the 'Great Eastern,' almost every vessel was deficient in that respect. All vessels, and particularly vessels of war, which had such heavy armaments to carry, ought to have the areas of the bottom, and of the upper decks, so equalised, that in whatever position the vessel might be placed, she would have the maximum power of resistance. He concurred in the principle that the armour plates should form part of the construction of the ship. Additional strength might, by that means, be obtained in the line of the upper deck. It had been correctly remarked, that the 'Great Eastern' was one of the most powerfully-resisting ships that ever floated. Her power of resistance was entirely owing to her cellular construction. There was a probability that, in future, the length of vessels would be increased, and their depth be diminished. If such an alteration in their proportions took place, it would be imperative to adhere to the known laws of construction in order to attain the maximum power of resistance. As a member of the Iron Armour-plate Committee, he concurred in the opinion of his colleagues, that nothing but a perfectly homogeneous plate could successfully resist the impact of shot. Armour plating, similar to that which had been used for the 'Warrior,' and which was about to be applied to the vessels of war in course of construction, might be considered to be the best, according to the present state of knowledge. With respect to the system which had been suggested, of placing several plates at some distance asunder, he had very little doubt that the experiments would prove its inutility. There could be no doubt that, taking a theoretical view of the case, a portion of the momentum of the shot would be absorbed in the ratio of the resistance presented by each successive plate, and that its velocity would be gradually diminished, as it successively passed through the whole of the plates, or until it was brought to a state of rest at some intermediate point by their resistance. But he believed, that in practice the resistance of the plates would produce no appreciable result.

Much depended upon the quality of the iron which was used for armour plates. It was essential that those plates should be of the most perfect quality that could be obtained, that they should have a great deal of fibre and very little crystallisation, that they should be ductile, and combine tenacity with softness. If plates of that character and of adequate thickness were attached to the sides of a vessel, he believed that they would be impenetrable by any ordnance which had yet been constructed.

As regarded the question of the mode in which the plates were to be fastened to the sides, he would remark that if a great number of bolts were used, they would have a tendency to weaken the plates. What was wanted to prevent deflection was a very strong framing behind, for the support of the armour plates. In the experiments which had been referred to, when the plates were supported by a backing of cast iron, the impression of the shot, or rather the injury done to the plates, was very trifling, compared with the indentations which were made in those which were supported by stone, or wood. In the case of the plates, which were backed with alternating layers of fir, india rubber, and cork, the shot went through those substances without the slightest opposition. The great desideratum was a perfectly rigid frame and skin upon which to bolt the armour plates. If that could be attained, he had every hope that the armour plating would resist the Armstrong, or any other projectile at present in use. It was proposed to construct a target of similar dimensions to that known as the 'Warrior' target, but with very strong ribs, and with a skin of 1 inch in thickness, firmly riveted to them. The internal structure would therefore be about three times as strong as that of the 'Warrior.' The experiments would then show, whether the resisting power of that target would be inferior, or superior to the wooden and iron sides of that ship. Although of the same dimensions, the target would be of rather less weight than the 'Warrior' target. It was possible that the jar and vibration of the shot might knock off some of the heads of the rivets. If that should prove to be the case, he thought that a thin layer of pasteboard dipped in tar, and inserted between the armour plates, would soften the blow and destroy the vibration. The results of these and other experiments, he had every reason to believe, would enable the Iron Armour-plate Committee to establish a system of sound principles for the construction of armour-plated vessels of war.

Captain Bedford Pim, R.N., said, that the present mode of fastening armour plates might be greatly improved. The methods of bolting, and tongueing and grooving, sensibly weakened plates, and rendered them less able to withstand the impact of shot. If an armour-plated ship, as at present constructed, encountered heavy weather and rolled continuously for some length of time, the plates would probably be loosened to a very injurious extent. He concurred in the correctness of the principle of making the armour plating enter into the structure of the vessel. An iron ship should be as nearly as possible one continuous plate. He had bestowed considerable attention upon the subject of the best mode of fastening on armour plates, but without any satisfactory result, until Mr. George Fawcus, of North Shields, suggested to him, that the principle of dovetailing might be adopted for that purpose. In conjunction with that gentleman he had tried a series of experiments, which had enabled him to produce the specimen of iron plating, joined by double dovetailed rivets and bolts, submitted to the Meeting. Figure 6 showed the details of the system.

Fig. 6.



Vertical Section. Elevation.

It was originally intended that the bolts by which the armour plates were to be connected, should have been of an angular shape, but upon subsequent consideration, a rounded form was adopted. The holes in the plate could thus be drilled, by which means a saving of time and expense was effected, and a better form was given to the bolt. A hole, or holes were slotted, or drilled through it, to admit a key, which was inserted close up against the backing. The end of the bolt was rounded off, and a thread cut for the reception of a nut, which being screwed up against the ribs of the vessel, brought all parts into close contact. He would draw attention to the fact that the edges of the plates were not proposed to be tongued and grooved, and by a process of thickening, which he intended to have tested, he hoped to make these portions of the plate the strongest instead of the weakest. The degree of closeness of the joint, which had already been attained, would be seen by the specimen before the Meeting. At present he could not say that it was water-tight; but he believed it could eventually be made so. The iron plates should be placed diagonally on the vessel's side instead of horizontally as at present, and be supported at each joint by a diagonal bracing, which should be rather stronger than the intermediate ones. Curved, or arched tubular beams, of great strength, should be used to support the upper deck, instead of the present weak form of structure, and tubular diagonal bracing might be used with advantage. If, added to these a vessel had a tubular stern-keel and stern-post, the chief requisites of naval architecture would be complied with, and by the adoption of the system of fastening he had recommended, each plate would be properly secured to its neighbour, as there would be no horizontal edges to open with the rolling of the ship. All working would thus be prevented, and the armour plating would form one continuous sheeting from stem to stern.

Mr. PHILIP THORNTON having, in his position of Assistant Master Shipwright, of Woolwich Dockyard, been engaged during the last seventeen years, in superintending the construction of iron ships, for war purposes, and having also been recently employed in the construction of ships of the same class as the 'Warrior,' would offer a few remarks upon the subject. The Author had admitted, that the three large ships now building for the Admiralty, possessed the two first of the conditions which were laid down in the Paper as indispensable, but asserted that they were deficient as regarded the two last. Now Mr. Thornton contended, that the vessels in question, in addition to possessing speed, and being protected by armour plating throughout their entire length, would also possess the advantage of a rapid and easy mode of replacing and repairing the armour plates. The system of tongueing and grooving had been abandoned, and another method was substituted, which would give quite as much facility for removing and replacing the armour plates, as that proposed by the Author. He disputed the accuracy of the principle of its being desirable that the armour plates should be made to enter into the construction of the vessel.

In discussing the effects of projectiles upon armour plates, too much attention had been given to the indentations on the outer sides of the plates, whilst very little attention had been paid to the appearances of the fractures on their inner sides. This had possibly arisen from the want of an opportunity of examining them. Fig. 7 showed the front, the back, and the section of an armour plate which had been fired at by the heaviest ordnance in use.

Fig. 7.

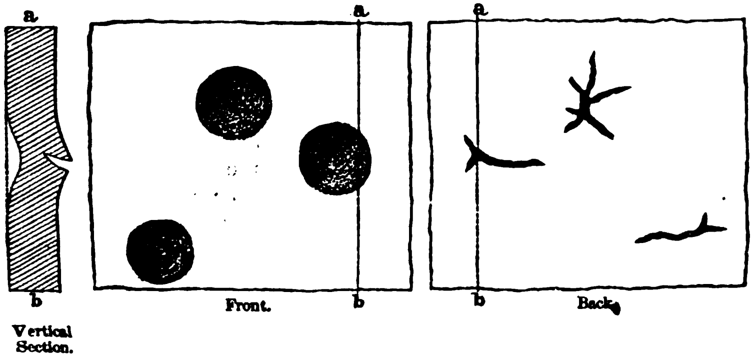
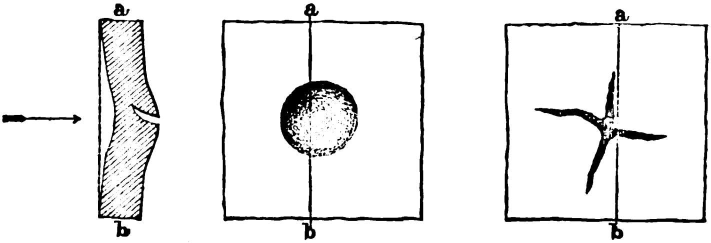


Fig. 8, in like manner, represented a plate of 4 inches in thickness, which had been fired at by an Armstrong 100-pounder gun, the plate being secured at an angle of 30°.

Fig. 8.



It would be observed, that the effects of the shot were similar in both cases, the plates being merely indented on the outer sides, while they were much fractured on the inner sides. Both plates had a backing of oak 10 inches in thickness. Looking at these results, he must consider, that as the vessel proposed by the Author would only have plates of 1 inch in thickness in the rear of the armour, without any intermediate wood backing, the inner skin, or side of the vessel itself, would be shattered if struck by a shot; and if that occurred below the water-line, the vessel would immediately commence leaking. As regarded the fastenings of the armour plates, he had observed, that in all cases in which the plates had been split, the fracture commenced at the bolt-holes and extended to the edges. If therefore a shot struck a plate fastened in the manner proposed by the Author, it would certainly fracture it. In the 'Warrior' the fastenings of the armour plates were placed 2 inches, or 3 inches farther from the edges of the plates, and he thought that plan was much more efficient.

Speed was considered to be primarily essential for iron-cased vessels; how long could that speed be preserved as compared with vessels constructed of timber? Until some provision was made for preventing the rapid fouling of the bottoms of iron vessels, timber ships must necessarily have the advantage. Mr. Thornton exhibited a cluster of barnacles 5 inches in length, as a small sample of a large collection which had covered the bottom of an iron vessel, in a period of between two and three years, and which had reduced the speed 30 per cent. It might be urged, that the vessel ought to have been placed in a dock before that period had expired; but it must be remembered that a ship of war was expected to remain on a foreign station from four years to five years. It was argued that the Admiralty ships of 6,700 tons were too large, and it was proposed to build a ship of 5,600 tons, which would carry the same armament, and possess greater speed. Mr. Thornton regretted that the data upon which this calculation was based had not been furnished, as he believed that further examination would prove it to be erroneous. It had also been urged that the 'Warrior' did not carry sufficient coal; but the vessel proposed by the Author would carry still less. It was said that the 'Warrior' rolled too much; but it appeared to him, that the vessel proposed by the Author would roll still more. Another reason urged in favour of a smaller ship was, that she would be lighter, if constructed according to Lloyd's rules for an ordinary first-class steamer; but all past calculations had clearly proved, that vessels of the size and mode of construction of the 'Warrior,' had the advantage of combining a maximum amount of strength with a minimum weight of hull. The Author had complained, that the Admiralty had the monopoly of the construction of vessels of war; that statement had already, to a certain extent, been disproved. It was shown that the leading iron-ship building firms had been called upon to design vessels for the Admiralty. That practice had indeed been followed as far back as seventeen years ago; but he could not say much as to the advantages derived from it, inasmuch as the only two ships which were really efficient, had been constructed by an Admiralty official. The question might be asked, why was the Admiralty in a better position than any private firm to construct vessels of war, whether of iron, or of wood? The answer was a very simple one. The Admiralty had been iron ship-builders for the last twenty years. They had now a fleet of forty vessels of iron, irrespective of those which were being coated with armour. They also possessed records and data of every large iron vessel which had been built. Most of the finest iron steam ships were the property of one, or other of the different Post-office mail companies, and before any ship was allowed to carry a mail, it was carefully surveyed by Admiralty officers, and every particular, as to her construction and scantlings, was noted and recorded. The Admiralty therefore possessed a greater amount of information on the subject of iron ships, than could possibly be found in any other establishment in the world.

Mr. R. TAYLERSON concurred in the advantage of increasing the strength of the internal structure of armour-clad vessels, and of appropriating to that purpose, a portion of the iron which was now exclusively employed as armour plating. But in his judgment, the most important point to be decided, as regarded the internal structure of a vessel, was the question, whether the greatest amount of strength could not be obtained, by a diagonal rather than by a longitudinal system of construction. In illustration of his views, he would briefly refer to some of the notices which, from time to time had appeared in the public journals, of the different melancholy accidents to iron vessels. In narrating the loss of the iron ship 'Eva,' the 'Times' stated, "that she was struck by a heavy sea, whereby all on board were alarmed by a loud report, which, on investigation, was found to have been caused by the breaking of the keel right in the centre, the vessel having broken her back." And again, as regarded the 'Birkenhead:' "She went on shore, and broke in two halves—400 of the passengers perished." The 'Liverpool Albion,' speaking of the then new screw ship 'Yorkshireman,' said, "She went on shore and broke in two." The 'Shipping Gazette,' in speaking of the loss of the 'Duchess of Sutherland,' said, "that in entering the Port of Aberdeen she broke in two halves." The 'Tayleur' shared the same fate, when 450 persons perished in the wreck. And in the memorable instance of the' Prince,' at Balaklava, the 'Times' stated, "that she struck on a sunken rock, filled with water, drifted, grounded, and in less than twenty minutes she broke in two parts, and all on board were immersed in the deep." The loss of the 'Transit,' in the Southern Ocean, occurred in a similar manner, her plating having split, and 600 tons of water having been pumped out of her within twenty-four hours. Many similar cases might be adduced, such as the 'Nemesis,' the 'Ida,' the 'Loire,' the 'Pacific,' the 'City of Glasgow,' the 'Ada,' and the 'Brigand, &c.' Unhappily, such disasters abounded in the public records, and in the 'Times' of the day on which he was speaking, the loss was recorded of a fine new iron ship, the 'New York.' All these vessels, to use the uniform language of these painful narrations, had "broken their backs," or, in other words, been broken into two parts, from the gunwale to the keel.

At present, iron ships were built upon a solid rectangular bar of iron. Now the keel, mechanically speaking, should answer the double purpose of a base on which to rest the frames, and from which to spring the outside plates, and also to act as a foundation of strength to the whole structure. The question naturally arose, was this solid rectangular bar the best and the strongest form to meet these requirements? It appeared to him that it was not, and that a hollow girder keel and keelson combined, would give an increase, in point of stability, of about 40 per cent. It was well known that the solid rectangular bar of iron had very little power of bearing a load, or of resisting a transverse strain, and that if it was placed on its edge, on props at the extreme ends, it could hardly sustain its own weight; but that laid flat, and kept in place by side attachments, as a hollow girder keel, its strength would be augmented, owing to its increased area, to resist transverse strain, to an extent of not less than from 30 per cent. to 40 per cent. That principle was exemplified in the tubular bridge which spanned the Menai Straits.

The reason of the inherent weakness of iron vessels, as at present constructed, was obvious. On looking at an iron ship of the ordinary construction whilst standing in frame, it would be seen, that the frames, without the plates, offered no resistance to any force tending to tear the ship asunder, in the direction of its vertical plane. The frames were placed vertically, and parallel to each other; and, instead of giving strength to the structure, they absolutely required the outside plates to keep them in their places. These frames were secured to the outside skin by rivets, in a direct vertical line from the gunwale to the keel, on each side of the ship, thus presenting a series of lines of weakness, owing to the displacement of the iron to make the rivet holes necessary for attaching the outside plates, just as was familiarly illustrated in the perforations in a sheet of postage-stamps. The frames also being in a vertical direction, and parallel to each other, could not offer sufficient resistance to any force, or strain having a tendency to tear the ship asunder transversely; while the frames being secured, as stated, to the outside shell, by rivets running in a direct vertical line from the gunwale to the keel, entailed one continuous line of weakness in that direction. In the case of the vertical principle, the line of resistance to any force, acting in the direction of the vertical plane of the ship, would be in a line with the shortest circumferential line of the body of the ship, thereby opposing the least amount of resistance to fracture coming in the direction of those planes; whereas, in the case of a ship built in accordance with the principle of fixing the frame diagonally, the line of resistance to forces acting in the direction of those vertical planes, would be diagonal to the circumferential line of the body of the ship, thereby opposing the greatest amount of resistance that could be given, at an angle equivalent to the inclination of the frames. The same reasoning would apply to the perforations in the plates, or outside skin, which, running in the same vertical line with the frames, also produced a series of lines of inherent weakness in the structure of the ship. This defect might be remedied in a similar manner, by making the line of junction of the butts of the plates diagonal, instead of vertical. Had the ill-fated ships, to which he had referred, been built on the diagonal principle, in all probability, the melancholy loss of life and property which had been recapitulated would never have occurred.

It might, perhaps, be urged, that in building a vessel on the diagonal principle, a greater amount of iron would be required for the framework, than if she were constructed on the vertical system. That might be the case, if it was necessary that the frames should be placed at the same distance as that adopted in iron shipbuilding on the vertical plan; but owing to the greater structural strength attained by the diagonal system, the frames of the diagonally-built vessel might be placed at a greater distance apart, and yet be able to sustain her armour plates, from stem to stern, without fear of strain, or injury. The greater buoyancy which would thus be obtained, would be a great desideratum for a vessel of war, and the additional strength for offensive and defensive purposes would be a valuable acquisition whenever it was attempted to decide an action by sinking by concussion.

Mr. W. A. Brooks said, that the late Lieut. Robert Wall, R.N., about thirty years ago, planned a system of ship-building in which the frames, or ribs of the vessel were to be placed diagonally. In the year 1836, a drawing in illustration of that system was published in the 'Appendix to the Report of the Select Committee of the House of Commons on Shipwrecks.' It showed diagonal ribs, or timbers crossing, and let into each other for a quarter of their thickness. In the system proposed by Mr. Taylerson, the diagonal frames, or ribs ran in one direction on the starboard side of the vessel, and then passed under the vessel and up the port side at an opposite direction, or inclination. Mr. Brooks considered the system adopted by Lieut. Wall was preferable, and submitted to the meeting a drawing, showing an adaptation of that plan, which he considered would enable the armour plating to enter entirely into the structure of a vessel of war. He proposed that the plates should cross each other diagonally, so as to form two thicknesses of plates riveted and bolted together. From the great strides which were being made in the construction of artillery, it was probable, that armour plating of 5 inches in thickness, would before long, be insufficient to resist the projectiles which might probably be launched against it. It would therefore, in his opinion, be better to construct the sides of ships of war strong enough to resist shells, and to let the solid shots, or bolts pass through.

Captain Halsted, R.N., believed, that no service gun had yet been produced, which was capable of doing any serious harm, to either men, or material within the sides of a vessel constructed like those of the 'Trusty,' namely, with a thickness of 25 inches of oak timber, covered outside by iron plates of 4 inches in thickness. The 'Trusty' was the only vessel built for the purpose of resisting shot, which to any extent had been submitted to experimental firing. Having witnessed and carefully recorded the experiments upon that vessel in 1859, he would mention a few of the more important results. Several shots were fired at her port side, from an 80-pounder, the first heavy gun constructed by Sir William Armstrong;—the vessel being placed at the respective distances of 200 yards, and 400 yards from the gun. The shots fired were of various materials, from hardened steel to ordinary cast iron; but after two days' firing only one shot entered the vessel. Two shots had struck almost identically on the same spot, only clearing each other by about 1½ inch. The first of these two shots struck the joint of the plate, and opened it to the extent of ¾ of an inch. The next shot struck this opening in its centre. The shot being 6 inches in diameter, 4½ inches of its area met with no resistance from the armour plates. The timber backing had already been shattered by the first shot, and the way being thus cleared, the second shot entered the ship, but it was quite spent, and did not reach a distance of more than 10 feet from the side; it, however, threw a splinter before it, a fragment from one of the plates, and that fragment crossed the deck and entered about 4 inches into the timber of the ship on the opposite side. That was the only instance, in which serious harm would have been done to any person at the main-deck guns of the ship. Another shot, of hardened steel, weighing 100 lbs., struck the vessel about a foot above the main deck platform. On looking for the effect of that shot on the inside of the ship, the place where it struck could not be detected, until some one noticed by chance, that the pieces of dried whitewash which had fallen from the side had formed a sort of conical figure upon the deck, and by the line of the apex of that cone, the place where the shot had struck the outside of the vessel was determined. That shot was fired at 200 yards. Since those experiments, Sir William Armstrong had produced his 100-pounder gun, but it was doubted, whether the 110 lb. service shot of that gun would be more destructive in its effect, than the 80-pounder gun had been when using the steel shot weighing 100 lbs. It was true that the diameter of the shot had been increased from 6 inches to 7 inches, but the amount of the charge had only been increased from 12 lbs. to 14 lbs. The gun was in other respects the same; and although the shot was somewhat heavier, yet the force of that shot was distributed over an area of 21·991 square inches, instead of, as formerly, over an area of 18·849 square inches. A 32-pounder Armstrong gun was also brought as close as possible to the vessel, and every effort was made to pass a shot through her, but, with the exception of two shots, which struck exactly upon joints, there was not one that would even lodge. The plates were damaged, no doubt, but only as the old armour in the Tower had been battered by the blows from swords and spears. The men who were inside that armour had, doubtless, escaped unhurt, and that was all the amount of protection which, in both cases, was required. He asked the Committee conducting the experiments to fire some shells against the vessel, but as the firing with the steel shot had produced no effect, they considered it unnecessary. The other, or starboard side of the 'Trusty,' was fired at from a Whitworth 80-pounder. The Whitworth gun proved to be superior to the Armstrong gun, inasmuch as the shot fired from it lodged in the side, but only one shot passed completely through, into the inside of the vessel. The plate struck was, however, defective. The shot cut a piece out of it, which was carried into the ship; but neither the piece of plate, nor the shot went more than half way across the deck. The timber behind the plate was also rotten. The inner planking, of 7 inches in thickness, could be compressed with the hand; and amongst the timbers of 10 inches in thickness there was extensive dry rot going on. This experiment did not, therefore, fairly represent the resistance of a sound ship of the same scantling as the 'Trusty.' Several of the armour plates were also bent, or 'buckled,' by the shot, but that was to be accounted for in a similar manner. The vessel had been built in a great hurry, of green timber, which had shrunk so much that in many places the wood backing was as much as 1½ inch distant from the plates, and when struck, they were driven against it.

As regarded the use of bolts for fastening the armour plates to the vessels' sides, Captain Halsted did not consider, that the bolt-holes weakened the armour plates to the extent which had been generally supposed. In the experiments which he had witnessed, where there was a solid backing in contact with the plates, there was no evidence of the commencement of cracks at the bolt-holes. In one case, a bolt had been struck by one of the shots. In the part which fitted into the plate, it remained of its original dimensions, but where it was imbedded in the timber, immediately behind the plate, it had been swollen, or 'set up' by the blow, the effect of the shot having been that of tightening the hold of the bolt on the wood. At one time it was urged as a strong objection against the use of bolts, that if one was struck, it would be liable to fly out, and act as a shot. No such instance had come under his observation, nor had he heard that such a result had ever occurred. As regarded the question of tongueing and grooving the plates, he would notice, that wherever a shot had struck within 6 inches of the edge of a plate, the whole force of the impact had expended itself in the direction of that edge, as presenting a line of least resistance; and while the remaining portion of the plate was comparatively free from injury, the edge was in most cases so completely smashed, as to render it evident, that the tongueing and grooving would not only afford no support to the plate struck, but would cause the damage from the shot to spread to the neighbouring plates.

Some doubts had been expressed as to the advantage derived from timber backing. One of the experiments, intended to be made upon the 'Trusty,' was that of firing a shot through one of the portholes, so as to strike the thickness of 25 inches of oak backing on its reverse side, but owing to the motion of the gunboat from which the shots were fired, the first shot—a 100-lb. shot of hardened steel—instead of entering the port as intended, struck the plates at its side, which it injured, but the shot did not lodge, being knocked to pieces by the resistance of the plate. The next shot—an 80-pounder of cast iron—passed through the port as proposed, and struck the timber on the opposite side, behind the corresponding plate to that which had been struck by its predecessor. This shot drove one-third of the plate about 50 feet into the air. The effect of these two shots showed the result produced upon two perfectly similar plates, the one having 25 inches thickness of timber behind it, and the other 25 inches thickness of timber before it, and thus afforded conclusive evidence as to the value of the wood backing.

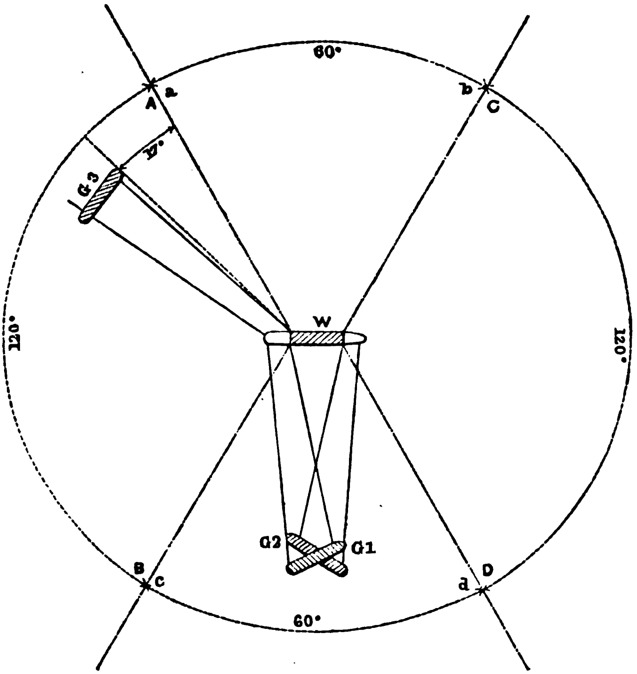
It was much to be regretted, that the results of the experiments upon the 'Trusty' had not been more carefully considered, by those intrusted with the designing and building of the armour-plated vessels of war which had since been constructed; as taken in connection with the results of similar experiments, upon the 'Meteor' and 'Erebus,' two other armour-plated vessels which had also been fired at: they afforded more trustworthy data than any which had since obtained. The 'Erebus' was an iron ship having only 5½ inches of thickness of teak backing between the skin of iron and the armour plate, and it was found that even a 32-pounder shot had a considerable effect upon her side. The first 68-pounder shot which struck her, although it broke to pieces, passed through the side, into the ship, in destructive fragments. It struck the corner of a plate and forced it inwards. The plate did not break up, but the corner was bent into the ship, piercing through the backing, and the iron skin; the side of the ship, for a space of 12 feet, or 15 feet in length, being bulged in, to the extent of 1½ inch. An experiment had been made at Shoeburyness, upon a target of similar construction to the sides of the 'Erebus,' but the armour plate being fastened by screws, after receiving the first five shots, tumbled down from the side it was intended to protect. There could be no question as to the inefficiency of screw fastenings. In the experiments at Portsmouth upon angulated plates, arranged on the system proposed by Mr. Jones, at an obliquity of 50°, the screws, used to fasten the plates to the target, were larger than those used in the experiments previously noticed, being 1⅞ inch in diameter; but every one of them broke, with the exception of those which were struck directly on the head, in which case, the momentum of the impact seemed to be sustained by the screw, in its longitudinal axis. The broken screws were found to have given way at the first part of the thread. Similar results ensued during the experimental firing at the Cupola shield of Captain Coles. Wherever screws were used, they all broke at about the first thread. Mr. Jones had expended £7,000 in order to exhibit publicly the value of the principle of deflecting shot; and while the naval administration of every other maritime nation entertained it, the English Admiralty had rejected it, and certain experiments made by the Iron Armour-plate Committee had been quoted in Parliament to prove that it was of no value. A second series of experiments had further demonstrated the advantage which would be derived from the adoption of the principle, in the construction of armour-plated vessels.

There seemed to be much uncertainty as to the precise thickness of plate, which would suffice to prevent the explosion of a conical shell. It was well known, that a spherical shell was rendered inexplosive, if it was fired against a plate ⅝ths of an inch in thickness. The experiments at Shoeburyness, with the Armstrong 80-pounder or 110-pounder gun, had also shown that a 1½-inch plate would render inexplosive, a conical shell when fired from those guns. The precise point between those two limits had not yet been ascertained. When the spherical shell was fired against a plate of ⅝ths of an inch in thickness, the shell was instantaneously broken up, and the powder of the charge not having time to ignite, became but a cloud of black dust, so that in effect, a spherical shell fired against a plate of iron of ⅝ths of an inch in thickness, might as well be loaded with sawdust as with powder. As regarded the thickness of iron plates which would afford sufficient resistance to break a shot, he would notice that in the experiments made on board the 'Excellent,' between 1849 and 1851, every description of shot and shell then in use, from 68 lb. solid shot to 32 lb. grape-shot, was fired against a target built on the model of the side of the 'Simoom,' having iron plates of only ⅝ths of an inch in thickness. In the Report of those experiments, it was stated, that every shot and shell was "shivered into innumerable pieces, passing on as a cloud of langrage with great velocity;" and the Reporter added, "This would be most destructive, and I firmly believe men could not stand behind it."

The present system of proving the quality of the armour plates to be used in war vessels was extremely imperfect. He was not aware that any of the experiments had been carried out under conditions analogous to those to which the plates would be subjected in actual service. The plates were tried on different kinds of backing, so that no real test could be afforded of their comparative quality; and their absolute efficiency for resisting shot could never be determined, when small targets were used to represent large masses, as, for instance, in the case of the 'Warrior' target of 30 tons weight, which was used as a substitute for a vessel of 9,000 tons burthen. There ought to have been a proper proof ship, and the established results of all such experiments should have been made public, so that the Government as well as the manufacturers, might have been acquainted with the exact merits, or deficiencies of the plates supplied.

As regarded the relative advantages and disadvantages of partial and complete protection, he would draw attention to Fig. 9, in which the larger vessel in the centre, marked **W**, represented the 'Warrior,' and the smaller vessel marked **G** 1, **G** 2, and **G** 3, represented the 'Gloire' in different angles of position. The arcs *a b*, *c d*, showed the portions of the circumference on each side covered by the protected guns of the 'Warrior,' at the limited angle of training which they possessed, namely, 30° forward and 30° aft. The other two arcs, **A B** and **C D**, of 120° each, represented the spaces within which, the protected guns could not be directed, and within which, her destruction could be more easily effected. Any antagonist, with complete protection, would naturally take up her position within either of the spaces **A B** and **C D**, as she could then only be opposed by the batteries in the weak ends of the partially-protected vessel.

Fig. 9.



The extreme ends of the 'Warrior' being only covered with plates of ⅝ths of an inch in thickness, every effect of firing from 10-inch shot to grape, &c., as shown in the Report on the 'Simoom' experiments, must equally take place in action on the ⅝ths inch plate of the 'Warrior,' or any other vessel of similar construction. Moreover, as far as the shot would range, they would be effective against those ends. The foremast, at the one end, and the mizenmast at the other, would furnish two lines of direction for aim, however distant the combatants might be. So vulnerable were vessels of the 'Warrior' class in their unprotected portions, that her sister vessel the 'Defence' was sent into harbour, to repair a dangerous hole in the ⅝ths inch plates in her bows, which had been made by a blow from her own anchor. One of the arguments in favour of partial protection, was based on the supposition, that an antagonist would be obliged to take up a raking position before she could destroy the unprotected portions at the bow and the stern, and that the effect of such a position could be nullified, by the resistance of the shot-proof bulkheads, which were placed across at the ends of the protected portion of the vessel. Such an assumption was, however, erroneous, as her destruction would be much more easily effected by a full-armoured vessel in one of the oblique positions, G 1, or G 2, when, if the broadside of her opponent was concentrated upon her bow, or her stern, every shot must pass through, and destroy both sides at once.

On the whole, he considered, that ships built on the principle of partial protection could never successfully contend against ships of equal force, built on the principle of complete protection. The following Table would, however, further illustrate and confirm his views on this subject:—

COMPARISON of the ENGLISH and the FRENCH ARMOUR PLATED Fleets, in respect to the principles of partial Protection, or complete Protection.

Points of Comparison.	English.	French.
Armour ships now afloat	4	6
Number of protected guns	80	252
Ditto on broadsides	40	132
Additional ships to be completed in 1862 . .	7	10
Number of their protected guns	222	360
Ditto on broadsides	112	190
Relative force at end of 1862 (ships) . . .	11	16
Number of their protected guns	302	612
Ditto on broadsides	152	322
Additional ships to be completed after 1862 .	4	Not known.
Number of protected guns	149	..
Ditto on broadsides	76	..
Total force afloat and building in ships . .	15	16
Number of protected guns	451	612
Ditto on broadsides	228	322
The protected guns in the broadsides of the several ships of the two Fleets will vary in number	from 7 to 21	19 27

The protected guns of the French ships were all 50-pounders, rifled to throw shot of about 90 lbs. weight. The British protected guns would, with trifling exceptions, be the smooth-bore 68-pounder. Each French ship like the 'Gloire' had two protected guns on the upper deck, capable of being fought on either broadside. That would be the case with only two of the British ships expected to be finished this year, and with only three more of those to be finished later. But beside the 451 protected guns of the British ships, they would have, as at present intended, 28 unprotected guns on their main decks, and 151 on their upper decks, making in all, 179 unprotected guns. The British aggregate would thus exceed the French by 18 guns. Hence arose the question—Was this great addition of unprotected guns, a source of strength, or of weakness? The 28 main-deck guns and their crews would be defended by iron plates only ⅝ths of an inch in thickness, which the Parliamentary Reports had proved were penetrable by every missile down to the 32-pounder grape-shot; and no experiment had been made as to whether they were proof, or not, against the conical and the incendiary shell. The 151 upper-deck guns and their crews would be defended by timber only, which would vary in thickness from 14 inches to 17 inches, but was not solid like the 18-inch teak backing of the 'Warrior.' That wooden defence was not penetrable by the same grape-shot as the ⅝ths inch iron plate; but, besides being liable to splinter, it was penetrable by every larger shot, spherical, or rifled, hot, or cold, and was likewise destructible by every shell, explosive, or incendiary. Taking the crews of the vessels, at a rough estimate, to be 20 men per broadside gun, the number thus exposed at the unprotected guns of the British ships would amount to 1,800; while the French guns, though less in total number by 18, were all protected, and could be fought without any exposure on the part of the crews except at the port-holes. Thus the two great principles of complete protection in the French fleet, and partial protection in the British fleet, were assuming proportions far more important than in the two first specimens respectively of the 'Warrior' and the 'Gloire.'

Should the British Admiralty persist in the principle they had adopted, the great national hazard of doing so, would be demonstrated by the issue of a war; on the other hand, should that Board give the subject a reconsideration, and determine to afford the guns and crews, the same protection throughout the entire length of the vessels, as that afforded by the French ships, it would be evident, that the ships now built, must be so entirely altered, as to the weight and disposition of their armour, that the experience they could furnish, in their present state, would be of little practical value. But assuming the existence of a doubt, as to the course now being pursued, an open experiment by all modern missiles, on the $\frac{5}{8}$ths inch iron plates and the 14 inch wooden sides, which would defend the 179 guns, with their 1,800 men, would, no doubt, furnish results either to confirm the principle of partial protection, or else to elicit an expression of public opinion, which would be sufficient to justify the adoption of the principle of complete protection.

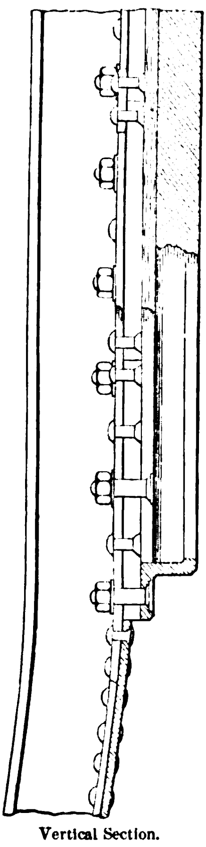
Mr. G. W. **Hemans** considered that, hitherto, in the structure of vessels the importance of strengthening the deck had not been sufficiently regarded. The extremely long vessels which were at present built—from 400 feet to 500 feet in length—must occasionally be in a position, where their weight would rest on a wave at each end, or, if they grounded, they might be supported by the middle, on a rock, or shoal. In either of those cases, the strains, to which the structure of those vessels were submitted, would be similar to those sustained by a hollow girder. But in the ordinary mode of building iron vessels, there was no provision for resisting the longitudinal strains, either of extension, or of compression, which would occur in the top of a vessel, looking at it as a girder; and, although thus unsupported, the ribs were placed at right angles, without any diagonal ties to resist the strains. It was admitted, that the armour plating, in many cases, weakened instead of strengthening, the vessels which carried it; and it must therefore be obvious, that additional strength would be required, in the structure of the hulls of such vessels. He might mention, that two of the steam-ships built for the Galway and American trade had to be withdrawn, on account of the weakness of their structure; and he thought the subject of making the decks more compact, by strong longitudinal girders on the cellular system, or on some other method, which would impart a corresponding strength to that which was given to the keel, would be deserving of the careful consideration of iron ship-builders.

Mr. **James Brunlees** said, that about two years ago, he had occasion to make some experiments upon puddled steel plates; and using a blunt instrument of 3 inches diameter, hemispherical at the end, upon a plate $\frac{1}{8}$th of an inch in thickness, he found that the resistance presented by it was equal to 24,640 lbs.; and with a plate of the same metal $\frac{1}{4}$ of an inch thick, he found the resistance to be equal to 52,080 lbs. Taking the mean of two experiments made by Mr. Fairbairn, with the same description of instrument, upon the best Staffordshire iron plates $\frac{1}{4}$ of an inch thick, the resistance was found to be only 16,792 lbs. Hence it appeared, that the puddled steel plates were three times stronger than the best Staffordshire iron plates. He did not mean to say that similar results would ensue when the plates were fired at by shot and projectiles, but he thought, that there was enough in these results to justify further experiments being made. With reference to the fixing of the plates on the sides of iron vessels, built in the ordinary manner, for commercial, or transport purposes, he suggested that at certain intervals bolts should be introduced, fastened with nuts inside instead of rivets (Fig. 10). A vessel so fitted, might be plated with armour, in the following manner. The bolts along the ribs could be withdrawn, and in the line of each rib a rolled beam of the form shown, or any other that might be preferred, could be bolted on to the skin. The armour plates might be inserted between these outer ribs, and allowed to slide down into their respective places. If the armour-plating was fitted on this plan, in the event of any plate being injured, there would be little difficulty in drawing it up, and replacing it by a new one. All the joints, of either form of plate, were also protected from the effects of shot, and the bolts being inside, were all covered by the armour plates. By the general adoption of vessels constructed on this system, the country might obtain the advantage, previously suggested, of possessing fleets of ships, equally well adapted with those now in use for all purposes of commerce and transport, but which, provided the necessary beams and plates were kept in store, could be armour-plated and turned into ships of war, at a few days' notice.

Mr. Pole stated, that armour plates of steel, as well as of combinations of steel and iron, had been tried by the Iron Armour-plate Committee, of which he was a member; but it had been satisfactorily shown, that no kind of steel, or steely iron, possessed good resisting qualities, when made in large sizes. It was true, that thin plates of that material had afforded great comparative resisting power; but these qualities did not seem to be attainable, by any means yet in operation in larger masses. When thick plates were tried, they invariably and signally failed.

The extraordinary toughness and strength exhibited by the steely materials, when made in small pieces, appeared to be due to the great quantity of work employed in their manufacture. The effect of work in strengthening iron and steel was hardly yet sufficiently appreciated among Engineers, and he would mention some remarkable illustrations of it which had lately come to his knowledge. Iron wire,

Fig. 10.



Vertical Section.

for example, was very much stronger than bar iron;—the wire, made in Manchester for the Niagara Bridge, withstood a tension of 45 tons per square inch, which was probably about double that of the iron bar from which it was made. The wire of the Fribourg Bridge, in Switzerland, bore about 50 tons per square inch. But he had lately obtained results, still more extraordinary, from some trials he had made of the strength of steel pianoforte wire, specimens of which he had found to bear the enormous tension of from 110 tons to 120 tons per square inch. This was the strongest material known; and probably hitherto, the very existence of such a strength could hardly have been suspected. The strength was probably due to the amount of manipulation of the wire in the process of drawing; and therefore, he conceived it afforded a useful hint to Engineers and to iron manufacturers, which might, perhaps, be hereafter advantageously applied. The Committee were of opinion, according to their present experience, that simple wrought iron was the material best adapted for defensive purposes, and that the qualities most desirable in this material were the utmost possible softness, combined with toughness and soundness of texture. If a plate was hard, it was always to a certain extent brittle, and this led to the cracking of the plate under blows—the special result which it was most desirable to avoid. The most perfect defensive plate was that which would resist the greatest amount of battering and knocking about without cracking; and that result was only to be anticipated in a soft material. The Committee were not inclined to recommend the use of very high-priced irons for armour plates, as the required qualities could be sufficiently well obtained in those of moderate cost.

The question whether rolled, or hammered plates were best, had also engaged their attention, but it was found, that each sort possessed both advantages and disadvantages, and improvement was still required in both processes, particularly for very thick plates. Hitherto the result of experience did not appear to warrant much confidence being placed in plates, either rolled, or hammered, above 5 inches in thickness.

The Committee was composed of six members, three representing the arms of the service most interested in the question, namely, the Navy, the Royal Engineers, and the Royal Artillery, to whom were added one eminent metallurgist, and two Civil Engineers, chosen for their experience in regard to iron. Their first active measure, after collecting the records of what had been previously done, was to take the evidence of the most eminent men in the manufacture and use of iron, in artillery, iron ship-building, and other branches of the subject: the call had been liberally responded to, and a valuable mass of evidence was thus collected, which would be published. The Committee had further invited Engineers, and others interested in the subject, to forward any plans, or suggestions which might occur to them as likely to be useful; and he had himself been commissioned to make a special communication of this nature to the Council of this Institution. The experiments of the Committee, though not exactly public, had been open to the inspection of all parties, who could show a reasonable claim to be present, and they had often been largely attended. The manufacturers of plates, for example, were always specially desired to be present, in order that their attention might be directed to the effects of the firing upon the material; it was pointed out to them, that improvement was desired, and might be reasonably expected in the quality of the plates, and that by personally examining the effect of shot upon them, they would be able best to form an opinion as to how improvements might most successfully be introduced. The Committee had found this system to work remarkably well. Their labours would probably be prolonged for some time, as many plans had yet to be tried. He hoped, on some future occasion, to be able to lay before the Institution, a fuller account of their proceedings.

Mr. GEORGE CLARKE considered, that if the quantity of iron proposed to be used in the construction of a vessel was distributed over the whole surface, in the form of a double skin, a greater degree of strength would be imparted to the structure than by the arrangement proposed by the Author. From the results of experiments which he had witnessed upon trial targets, he believed, that projectiles from the 100-pounder Armstrong, or from the 68-pounder smooth-bore gun, at a high velocity, would penetrate into, or break through, a plate of iron 6 inches in thickness. The armour plating proposed by the Author might be considered as a series of panels of that thickness, the armour plate being 5 inches in thickness, and the skin 1 inch in thickness. Moreover they were fixed, exactly in the position in which a plate of iron would be placed, for the purpose of punching a hole through it, a hollow space being left under the portion where the force was to be applied, by which means it would be more easily penetrated. The same causes would also render the plate more liable to curl up at the edge, or as it was ordinarily termed, to buckle. In nearly all the cases in which the effect of buckling from the impact of shot was most apparent, the backing had been of wood, which not offering sufficient resistance, had been driven in, and the buckling had taken place. It was worthy of observation, that in all the experiments which had been made, the principal damage had been caused by the backing being of wood, and its yielding to the effect of the blow. In the experiments upon the 'Warrior' target, that effect was most distinctly shown. When the last shots were fired at it, the wood was driven in, and the iron was crushed into the wood, whilst the ends of the plates were torn away from the backing, so that the bolts at the extremity were drawn out 1½ inch, or 2 inches from their bearings, whereas when there was a hard backing of iron, as in the case of Mr. Fairbairn's target, whenever the projectiles struck over the angle iron ribs, representing the timbers of the ship, the iron did not yield, and there was a very slight impression, or indentation made upon the plate itself. One of the small targets, constructed of plates 2½ inches in thickness, backed by cast iron, was fired at with a 40-pounder shot, without producing any impression on the plate, except an indentation of 3 inches in diameter and ½ inch in depth. A 100-pounder, or 120-pounder shot, was afterwards fired with a full charge. This struck the plate towards the edge, and slightly grazed the head of one of the bolts. Where the plate was struck outside the bolt, no impression was made, except an indentation ¾ of an inch in depth, and 6 inches, or 7 inches in diameter, and no other damage was done to the plate. The inadequacy of the bolt as a fastening was however clearly shown. On being struck, it acted as a wedge, burst part of the plate away, and broke into fragments a portion of the cast-iron backing. Under any circumstances, the bolt was a defective fastening, being exposed to the impact of projectiles, it became if struck a source of damage to the plate, which moreover was weakened by the bolt-holes. The system of fastening proposed by the Author aggravated these objections. The bolts being placed in lines along the edges of the plates, left only an inch of iron between the bolt and the outside of the plate; and if a bolt-head in this position was struck by a shot, it would fracture the plate and separate it from its fastening.

The results of the different experiments had clearly shown, that the most essential question, as regarded the armour plating, was the character of the substance upon which it was fixed. If that backing was of sufficient hardness, rigidity, and strength of structure, to resist the crushing effects of projectiles, their penetrating power would be reduced to a very small amount; and much thinner plates, than those now adopted, would answer the purpose of resisting the effect of projectiles. The question of the backing of the armour plates was intimately connected with that of the mode of fastening them. If fastenings were inefficient, the armour plate could not resist the effect of projectiles. It was true that a backing of solid iron of sufficient thickness could not be adopted, on account of its great weight; but he believed that a backing might be composed of a series of cells, which by presenting their ends, instead of their sides, to the armour plating, would effectually support it. In constructing such a cellular backing, the diameter of the projectiles, which would probably be used against the vessel, should be taken into consideration, and the cells should be made of such a size as would ensure, that at every blow at least two cells would be covered by the diameter of the projectile. With such a cellular arrangement for the backing, he had no doubt that projectiles, at the highest velocity, might be successfully resisted. From models and drawings which he had prepared, he found there would be an advantage in distributing the greater portion of the material used in armour-plating a vessel, in strengthening the backing. The weight of the iron and the wood together in the 'Warrior' was equal to a plate 6½ inches in thickness. By properly distributing the amount of iron to which such a thickness of plating was equivalent, armour plates of 2½ inches, or 3 inches in thickness would be sufficient; and the remaining portion of the iron, being put in a cellular form, some inside and some outside the skin of the vessel, a backing and plate would be obtained, which together would have a thickness of from 20 inches to 24 inches, and by some such combination, the problem of rendering vessels invulnerable to shot would no doubt be solved.

Mr. G. P. Bidder (Past-President) said, in the course of the discussion it had been inferred, that because there was a department of the Government specially charged with the investigation of the subject of the construction of armour-plated vessels of war, little good would be obtained by its being again brought before the Institution. He however held a contrary opinion, and he considered, that great public benefit would be derived, from a fair and open expression of opinion, on the several topics which had been introduced by the Paper and the discussions. Questions of a similar character had been repeatedly brought before the Institution; and he had no hesitation in saying, that both the science and the art of iron ship-building had thereby been benefited. The observations which he had made with regard to the capabilities of the 'Great Eastern' to resist the impact of waves, had been fully sustained by her performances. Whatever mischances might have befallen her, none of them were due to her size, or to the method of her construction. When the question of the National Defences was before the Institution, he had pointed out why three-deckers should no longer be used to form the line of battle;[1] and since then, even the three-decked vessels on the stocks had been cut down to one deck, and the old three-decked ship of war had become obsolete. He had also pointed out, the expediency of making great alterations in the rigging, and at the present time the Government officials were trying, whether the rigging of vessels of war could be so reduced, as to enable them to send down their yards in time of action. Many other changes had been first mooted at previous meetings, and therefore it could not be correctly stated, that the discussion of these subjects by the Institution was unattended with public benefit. It had been said that the Admiralty possessed a larger stock of knowledge, as regarded iron vessels, than Civil Engineers. He was not, however, prepared to admit that such was the case; but if that Board had a maximum amount of knowledge and experience, he could only say that it had produced a minimum result. Eventually compelled to admit, that iron must enter largely, if not solely, into the construction of the Navy, they had resisted that change to the last, and had used ships for the purpose of experiments, apparently with the sole view of retarding its introduction. Up to the present time, the proper class of vessels to be built, had not been determined upon. Vessels of all kinds were being built, some fast, some slow, some weak, and some strong. Although it could not be correctly stated, that England had not a fleet, capable of meeting that of any other nation, yet the vessels were neither so numerous, nor of that capacity, or efficiency as the nation had a right to expect, in exchange for the very large amount which had been expended. That inadequate result was mainly due, to the reluctance of the Admiralty to introduce the improvements which modern science had, for so many years, been pointing out. Socially and politically, it was of the utmost importance, that the speed and capacity of vessels should be increased. It was easy to account for the slow advance in these points of the English mercantile marine, as, owing to the laws for determining the tonnage of vessels, ship-owners had been reduced to the necessity of carrying 1,600 tons of cargo, under 600 tons of registration. But the same argument would not apply in the case of the Navy. In his opinion, the Admiralty had failed, because of the exclusive system which they had pursued, and their strict adherence to routine. He would cite as an instance, that up to the present time, whatever the build, or the form of the ship, there was but one common regulation as regarded the size and disposition of the spars. In the clipper-built vessels of the Navy, the masts were placed exactly as they were in the old form of ships. The position of the foremast in the 'Warrior,' might be taken as an illustration of the extent to which their science in naval construction had advanced. He had therefore no hesitation in saying, that the public investigation of these subjects had an undoubted tendency to let in the light of true science, by dispelling the clouds which hung over the official mind.

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[1] *Vide* Minutes of Proceedings, Inst. C.E., vol. xx., p. 518.

The Author had put before the Institution, a practical method of using the defensive armour, supposed to be necessary for ships of war, in such a manner as to add to the strength of those vessels, but the extent to which the armour, when fixed, might be capable of resisting the impact of modern projectiles, was a question which experiment alone could decide. The other matters alluded to in the Paper were, however, of more importance, as the primary question to be solved, was that of the form and capacity which were necessary for vessels of war. It would be well to review the different duties they would be required to perform. Vessels of war were needed, first, for the attack of forts; secondly, to form a powerful line of battle; and thirdly, to protect commerce, by acting as convoys to merchant ships, and also by chasing, capturing, and destroying the cruisers and privateers of the enemy. As regarded the first point, the result of the last war with Russia had clearly proved, that the former class of men-of-war was incompetent to cope with land batteries. They failed signally at Sebastopol, and were only saved from destruction by being hidden in their own smoke. Looking to the fact, that it was now proposed to protect forts with iron plates 10 inches in thickness, and where they could use the heaviest modern artillery, it would be equally impossible, that such a vessel as the 'Warrior' could successfully contend against such forts, as would probably now be built. If it was proposed to attack forts, in which modern improvements had been adopted, it would be necessary to provide a special class of vessels for that service. Whether it was possible to do so, he would not then discuss. The second point to which he had referred, was the difficult problem of forming a line-of-battle with modern artillery. He thought there must be some misapprehension as to the details of the experiments upon the 'Trusty.' It was true that when the firing with the Whitworth 70-pounder guns took place, some of the shots did not go through the 4½-inch plates. Yet it was obvious that, with the Whitworth gun, a bolt could have been fired through that thickness of iron. The rear of the bolt might also have been constructed as a shell, so that when the iron was perforated, the timber would have been blown to atoms, and thus have created great destruction between decks.

The 'Warrior' was a complete failure, except in one respect, —that she was a fast vessel. It was admitted that she did not steer, but that defect might be remedied. The principal defect was, however, that notwithstanding her great length—400 feet—she had only about twenty-four protected guns, while a length of 100 feet at each end was left unprotected; an enemy in close action would undoubtedly assail those weak points. Her spar-deck was also entirely unprotected. It was impossible to combine in one vessel all the qualities essential for general service, unless she was built of such a size as would render her practically useless, except on some occasion which she might never be called upon to fulfil. Speed could not be combined with the necessary stowage for her crew and for coal. The appointment of the Iron Armour-plate Committee had undoubtedly given a great stimulus to the manufacture of iron plates of a superior quality. As regarded the deduction which had been drawn from their experiments, he admitted that the explosive power of the powder, regulated the mechanical effect of the shot, and that the mechanical effect itself could be measured by the indentation, or fracture of the plate, but it was an error to say, that the power of breaking a plate was determined under all circumstances by the force of the powder. Let it be assumed, that a shot of 100 lbs. weight, with a given velocity, broke a plate of a certain thickness, and then let the same weight of metal be distributed into a hundred shots weighing 1 lb. each. If those shots were fired in succession against a similar plate, it would be probable they would never break, or even indent it. As far as he understood the deductions which had been drawn from the experiments, the relative resistance of a plate was assumed to be as the square of its thickness, while the relative effect of a shot was assumed to be, as the square of its velocity, multiplied by its weight. Now, it was quite true, that great effect was produced upon the sides of the 'Trusty,' by firing at her with a Whitworth gun at 200 yards' distance, and that great damage was done to the plates whenever the shot hit them at right angles. But how were similar conditions to be unfailingly secured in action? An enemy would not regulate his motions to suit the convenience of his opponent; the exact distance also, could not be determined, and the firing must be subject to all the uncertainties arising from the motion of vessels at sea. A fight might be continued for an entire day, without a single shot being fired under circumstances similar to those of the experiments. It appeared to him, that the choice must be made, between having an invulnerable ship, and therefore restricted in speed and capacity, and a ship which might be rendered comparatively invulnerable, but which would possess the element of speed, in a high degree. Taking the latter view of the case as the correct one, a ship might be constructed, with the whole of her sides covered with plates 2½ inches in thickness. With that thickness of metal, there might be great latitude as to armament, space, and capacity, while the degree of strength would be much greater than that required for any of the ordinary circumstances of sea risk. The plates of the 'Great Britain' were not more than ¾ inch in thickness, yet that ship, after being for a whole winter on shore in Dundrum Bay, was got off, and although built twenty years ago, was still a fine sea-going ship. A vessel, with plates of 2½ inches in thickness, might not resist a heavy projectile, fired from a short distance, but the probability was, that she would be missed by ninety-nine out of one hundred shots.

As regarded speed, there could be no doubt, but that it was a primary element in naval warfare. It enabled a naval officer to close with his enemy and to board if required. A slow ship could not board a fast one, while at the same time, it would be impossible that the slow ship could get away from her fleeter antagonist. Whether the tactics of sinking by collision were adopted, or not, a vessel ought to be able to take her option of either fighting at a distance, or of closing with her enemy, but neither of these objects could be accomplished without speed, and therefore speed was a qualification, which as a primary element, should be attained at any cost.

Mr. **Samuda**, in reply, said, that his object in writing the Paper had been to reduce under as few heads as possible, the characteristic points, to which he thought attention should be turned, in the construction of a vessel, protected with armour plates, and suitable to cope with the existing description of artillery. Of the four points which he had laid down as indispensable, he considered speed the most important; and with scarcely one exception, the necessity for its existence had been recognized in the course of the discussion. As regarded the question of entire protection, the whole progress of opinion and events seemed to show its necessity, but the problem, of uniting it with the other indispensable conditions, had greatly increased in difficulty. Those countries which, like England, were about to go to the expense of large armour-plated vessels of war, had considered perfect protection to be indispensable, and had entirely dismissed the erroneous plan of only protecting the middle portion of the vessel. It was scarcely to be believed, that a nation, who like the English, had been the first to build ships with iron frames and iron casings, should resort to such an expedient. It was to be hoped, that the examples of partial protection would be confined to the vessels already afloat. The third condition, that of the armour plating being capable of easy replacement and repair, would alone develop its full importance in actual service, but it was a matter strictly within the province of the members of the Institution, and of those following mechanical pursuits, to discuss in all its bearings. It was impossible to make ships absolutely invulnerable, inasmuch as the improvements in artillery would always overtake the improvements in defence. A vessel which could not replace, or repair the injured portion of her armour plating, would have her efficiency greatly lessened, and would be placed at a serious disadvantage, when opposed to vessels, the armour plates of which could be easily repaired, or exchanged for new ones. A very little experience had proved, that the edges of the armour became curled up under the impact of shot and projectiles; but when that was discovered, one error was employed to remedy the defects which had proceeded from another, and the tongue and groove fastening was introduced. As that system of fastening was now about to be abandoned, he had proposed the system of fastening, the details of which he had laid before the Institution. He did not say, that the method was the only one by which the existing want might be supplied, but he would strongly urge the general proposition, that a system of fastening which would admit of the plates being easily repaired, or replaced, was an indispensable condition in the equipment of modern vessels of war.

The fourth proposition—that the armour-plating should enter into the composition of, and add strength to, the structure of the vessel, had not been doubted, or denied, although the special means by which he proposed to accomplish that result had been considered, by some persons, to be insufficient. If a vessel was to be taxed by putting a large amount of iron upon her top-sides, it was imperative, that that material should enter into the structure of the ship, instead of straining her, by its weight. He believed the plan which he had proposed would effect that desirable object, and he would add a few words in further explanation. A vessel without armour, and with sides merely completed like any ordinary iron vessel, might be considered as a girder, the top of which was represented by the sides of the ship. When stranded, or lying upon a rock, before she could break up, the sides of the girder, including the skin of the ship, must first be torn in two from the top. Experience had, however, repeatedly proved, that plates of ⅝ of an inch, or ¾ of an inch in thickness were sufficient to withstand the ordinary resistance brought on the sides by the sea. It therefore followed, that if on the top edge of the girder, an additional longitudinal rib was placed of 12 inches in depth and 2½ inches in width, it would, in effect, be an additional girder over the whole length of the ship; and when the armour-plates were fastened to it by the bolts, so that every plate would butt against the neighbouring plate, it followed that before those plates could separate from one another, the bolts from end to end of the vessel must be broken, or else the plates must tear away the 2½ inch web from the top of the ship. Hence, if the power to break the bolts was greater than that necessary to tear the 2½ inch rib asunder, the strength of the top rib would be increased to the extent of 2½ inches sectional area, and thus an additional skin was given to the outside, the minimum strength of which was represented by 2½ inches of thickness; and the strength of that 2½ inches would be conveyed to a plate of greater thickness, throughout the entire exterior of the armour skin of the vessel.

It was now more than two years, since he had first laid his proposals on these points, before those whose consideration and adoption of them might have produced an earlier result, in the direction which he hoped the building of armour-plated vessels would eventually follow.

As regarded the wood backing, it was obvious, that the elasticity of wood was much greater than that of iron; or, in other words, the particles of wood were much more distant than those of iron, so that when it was attempted to support the iron against the impact of a shot, by means of wood backing, the iron was broken, before the wood was sufficiently compressed to yield the required support. It might, therefore, be said, that practically the wood backing offered no support to the armour plating, except in the case where the momentum of the projectile would have been insufficient to break the plate if it stood alone; when it would serve to distribute the strain, more uniformly over the back of the plate. But there was another serious objection to wood backing. If the armour plate was fastened to iron, and the contact was made complete by only a small interposed packing, then it would be held fast without movement; but it was not so when the armour plating was fastened upon wood, owing to the different conditions of the two materials. With the working of the ship, the holes in the wood became larger, whilst the bolts became smaller; and thus, after a certain time, the fastening of the armour plates became more and more loose, until, ultimately, the whole process of fixing the armour on to the wood backing would have to be repeated.

It was generally admitted, that the resistance of a plate to the crushing force of a projectile was in the ratio of the square of its thickness. But it had been urged, that an additional advantage was derived from the great thickness of the wood backing. As regarded that theory, he would point out, that there could be no additional resistance, without a corresponding weight of material. It should be remembered that the thickness of armour plating in a ship was limited to the weight she could bear, and that, in consequence, any improvement should rather have the effect of taking away from, than adding to, the weight which the ship had to carry. For armour plates of 4½ inches in thickness, according to the received formula, the relative resistance would be equal to $4{\cdot}5^2 = 20{\cdot}25$. In the 'Warrior' the backing consisted of 18 inches in thickness of teak, which, for the same surface, was of equal weight to an iron plate of 1½ inch in thickness. Supposing that 1½ inch was added to the armour plating, so that its total thickness was 6 inches, by the same formula the relative resistance would be increased to 36, instead of 20·25. Would any one say, that the iron plate and wood backing combined would present that amount of resistance to the impact of shot?

As regarded the mode of fixing the armour plating, which he proposed, every fastening of the armour plates was distinct and separate from the fastenings in the skin, and therefore the plates might be removed, and exchanged, even under fire, with no greater risk than had been run by thousands of sailors when plugging shot holes in timber ships of war.

In reference to the 'Warrior,' Mr. Samuda wished it to be distinctly understood, that on many points he considered she was a very fine vessel. He had heard on good authority, that no communication had been made, as to her alleged excessive rolling, by the officers in charge of her, and therefore he was inclined to disbelieve that such was the fact. It had been argued, that, inasmuch as the designers of the 'Warrior' had not succeeded in giving her a displacement sufficient to enable her to carry her armour plating to her extremities, it was quite impossible that a vessel of smaller size could do so. Under these circumstances, and to controvert that opinion, it would be well, that he should give the following general outline of the character, dimensions, and displacement of the model, which he had submitted for the inspection of the meeting:—

Length	382 feet
Beam	55 „
Depth from main deck . . .	31½ „

When drawing 25 feet of water:—

The displacement would be . .	8,505 tons
The midship section . . .	1,145 square feet
The midship port cill above water .	9 feet

The particulars of the displacement were—

Iron work in hull	3,300 tons
Armour-plates (5 inches in thickness in midships, and reduced at the ends to 3½ inches), and also longitudinal ribs.	1,600 „
Wood work	930 „
Outfit, and specified Admiralty weights, stores, &c.	1,000 „
Engines of the same horse-power as the 'Warrior'	875 „
Coal	800 „
Total displacement . .	8,505 tons

The lines, upon which the proposed vessel was to be built, were somewhat finer than those of the 'Warrior,' and the body of the vessel was to be fuller. If the same mechanical power was applied to her, as to the 'Warrior,' she ought to have a speed of 14½ knots per hour at her deepest draught, and a speed of 15 knots per hour with one-half the stated supply of coal.

The idea that the momentum of a projectile would be destroyed, or to a great extent neutralized, by a series of plates placed at a given distance, although it was completely fallacious, was by no means novel. Some time back, in consequence of a proposition laid before him by an officer of artillery, Mr. Samuda made some experiments to set the question at rest, and he found, that whether the plates were placed at intervals apart, or close together, no appreciable difference was found in the result. The depth and extent, and the shape of the penetration of the shot, were the same under both conditions. He also made a further experiment, of the effect of the shot on an united mass of iron, of the aggregate thickness of the several plates, and in that case, the resistance was much greater, and in conformity with the law which had been previously enunciated.

Although he had expressed the opinion, that iron vessels of war would eventually supersede those built of iron and wood combined, he still thought, that the Government was pursuing a right course in utilising the present wooden ships by plating them; and he believed that the transition, from wood to iron, would not be the less effectual for being gradual. Those ships would be effective and valuable ships for a time; and, looking to the necessity which existed for obtaining a mail-clad navy, within the shortest possible period, and to the length of time, which iron structures necessarily occupied in building, he had no doubt, that the Government was exercising a wise discretion in fortifying the wooden vessels, with iron armour plates, to the extent to which they were capable of carrying them. At the same time, this expedient should only be considered as a provisional measure. In armour-plating wooden vessels, iron longitudinal ribs should be let into the wood back, to support the edges of the plates, upon a similar system to that which he had proposed for iron vessels. The plates should be bolted to the timber sides, and the longitudinal ribs, while they prevented the edges of the plates from curling up, would add strength to the sides of the vessels.

Mr. Hawkshaw,—President,—said, that the importance of the subject which the Author had so ably brought before the Institution could hardly be overrated. The question of the best form and mode of construction of iron-plated vessels of war, probably involved a larger expenditure of money, than any other which could be submitted for consideration. The present progress in the science and art of attack and defence, would, no doubt, lead to the modification of the navies of all maritime nations. The pecuniary question alone, might form some excuse, for the length and proportions which the discussion had taken, and the mechanical portion of the subject also presented great difficulties. Steam-ships of war, even before the new system of warfare was propounded, were already very complicated machines. There was the question of steam power, and of sailing power, and of the relative value and proportions of each; and to a country like Great Britain, having to defend its dependencies even at the Antipodes, as well as the narrow seas at home, it was evident, that when the problem to be determined, was the proportions that those two powers should bear to each other, in an ever-varying sea service, the question was not of easy solution. When the subject of steam power was dealt with, the capacity for carrying, and the possibility of obtaining supplies of coals, must necessarily be studied. The difficulties connected with a regular supply of coal, forbade the abandonment of sailing qualities; but when, in addition, it was proposed to render steam-ships of war invulnerable, it was evident that the difficulties which previously surrounded the subject were greatly augmented. It seemed to be expected, that the Admiralty, or some other department connected with the Government, should solve these very complicated questions by inspiration, and grievous complaints of the tardy proceedings had been made. But it should be remembered, that there was a general proneness to find fault, and that under any circumstances, it was much easier to complain of others, than to solve the existing difficulties. Now he was not at all certain, that the propositions, which had been laid before the Institution by the Author, could ever be fully accomplished. He hardly at present believed in the possibility of rendering ships of war quite invulnerable, and at the same time making them swift, lively, easy to manœuvre, and also of effecting such a disposition of the iron plates, as would admit of their being put on and taken off at pleasure. In making these remarks he did not wish to discourage investigation on the subject; for although he considered it a matter of doubt, whether all these qualities could be combined in one vessel, yet the Author was quite right in putting them forward as desiderata. There was one point connected with the use of iron which might, however, greatly modify any opinion as to the propriety of its universal adoption in naval construction. He alluded to the fouling of the bottoms of iron ships. It was generally admitted that ships of war must possess great speed, and therefore, great mechanical power and capacity for coal; but what would this avail, if the bottom of the vessel accumulated such a mass of organic matter, as would neutralize her speed and render her a slow, instead of a fast vessel? It was to be hoped that modern science might aid in remedying that drawback. If no other expedient presented itself, it might be worthy of consideration, whether the bottom of an iron vessel could not be covered with timber planking, so that copper-sheathing could be placed outside of it in the usual manner. There might be some difficulty in attaining proper fastenings, but it did not seem to him to be insuperable.

The suggestions which had been put forward by the Author were valuable, and many of the other proposals were very ingenious. It seemed possible, that iron vessels of war could be so constructed, as to be proof against shells and a considerable amount of firing with ordinary shot. He must, however, confess that his own preconceived notions had been greatly modified by the experiments which he had witnessed at Shoeburyness. He had there seen the effects of the new artillery, and he believed, it would be be well for all who thought they could make a perfect and invulnerable vessel of war, to refrain from expressing strong opinions until they had seen the effects which had been produced upon the targets. The fact was, that not only was the experimental plate generally knocked to pieces, but also the framework beyond it. The effect of the firing upon these targets had convinced him, that after heavy firing the attachment of new armour to the skin, would not be so easy an operation as it was thought to be, by those who seemed to assume that the skin would remain perfect.

The primary object of the investigations of the Iron Armour-plate Committee was to ascertain the best kind of iron for resisting shot and projectiles, and in consequence, they did not devote much attention to questions of construction. The trials appeared to have proved, that iron of the toughest, but not of the hardest quality, was the best for the purpose of resistance. It might have been readily surmised, that thick plates were stronger than thin ones, but the proper thickness still required investigation. Even admitting, that the strength of armour plates, other things being the same, varied as the square of their thickness, and that plates of 5 inches, or 6 inches in thickness were the best for resisting shot, the question arose, How was a ship to be built with plates of that thickness? The practical solution of that question had occupied the attention of the Institution, and undoubtedly it presented the principal difficulty. Admitting all the premises as regarded the proper thicknesses of the armour plates, it was still necessary to put together large masses of iron, so as to make a vessel, say, of 350 feet in length; and the structure so put together would, under certain circumstances, be required to fulfil the conditions of a beam, and under others, those of a bridge. It would also be liable to cross strains in every direction, and should be so constructed, that every particle of material should in some way, or another, add to the strength of the structure. He certainly had seen no plan which would answer all those conditions, and indeed he had not seen any in which the 5-inch plates would be of the slightest benefit in resisting the strains upon the internal structure, or hull of the vessel. He had designed two targets for the Iron-plate Committee, and in doing so, he had merely considered the best mode of structural arrangement. They were made of plates of such a size and thickness, as to prevent the joints from coming in the same line with each other, and to secure as nearly as possible, a perfect bond and a uniform strength throughout. The iron in the targets was also disposed in such a manner, that each plate should bear a strain, as nearly as might be, in all directions. He considered, that such a mode of construction would be that which would be most available for fixing armour plates to a vessel's side. But he was quite aware, and he had stated before the targets were made, that plates so laminated, would not be so successful in resisting shot, as if they were welded into one solid mass. On the other hand, such an arrangement of the plates afforded great facility of construction. By its means the thickness of the plating could be increased, or diminished as required, and the iron could be wrought into any form which might be thought desirable. A ship, or a fort, could thus be made more structurally perfect, than by any other system with which he was acquainted; and at present, he was not aware of any other plan so good for securing a homogeneous structure.

The Institution and the public were much indebted to the Author. The Paper had elicited a great number of opinions and facts, and had led to careful consideration of the subject of the construction of vessels of war, which would produce benefit. It would be well, however, to bear in mind, that all the experiments at Shoeburyness, had been made with what, in the lapse of time, might probably prove to be small artillery, namely, 68-pounder and 100-pounder guns. It was possible, that before long, guns might be constructed capable of throwing projectiles of 300 lbs. weight. It would, therefore, be a difficult task to make the invulnerability of vessels keep pace with the improvements in modern artillery; and even if such a result could be attained, it could only be done by making a vessel as heavy and unmanageable, and as unfit for warlike purposes as the men-at-arms of the middle ages, who were frequently smothered in their own armour. The problem, which some supposed the Admiralty ought to have already solved, might not be settled for some years. It was, further, possible that mistakes of greater, or less magnitude would be made, before a satisfactory result could be attained. To make a ship swift, lively, manageable, perfectly invulnerable, and yet easy to repair, required no ordinary amount of research, ability, and actual trial; but, looking at the present position of the question, he thought that the point to be aimed at in naval construction, was to secure a swift ship, which would be perfectly manageable, and easily handled; and, having done that, to make her as invulnerable as possible; but, above all, to be careful not to sacrifice speed, for the sake of securing any other quality.

February 4, 11, 18, and 25, 1862.

JOHN HAWKSHAW, President,
in the Chair.

The discussion upon the Paper, No. 1,049, "On the Form and Materials for Iron-plated Ships, &c.," by Mr. J. D'A. SAMUDA, was continued throughout these evenings, to the exclusion of any other subject.

At the Meeting of February 4, the following Candidates were balloted for and duly elected:—JOHN ANDERSON, SIR CHARLES TILSTON BRIGHT, RICHARD CARDEN DESPARD, ARTHUR WILLIAM FORDE, GEORGE WILLIAM MAYNE HELLYER, and HENRY PEVERIL LE MESURIER, as Members; HENRY JOHN GIRDLESTONE, CONRAD ABBEN HANSON, ALDERMAN DAVID SALOMONS, M.P., JOSEPH FOX SHARP, and CHARLES FREDERICK STUART SMITH, as Associates.

March 4, 1862.

JOHN HAWKSHAW, President,
in the Chair.

The following Candidates were balloted for and duly elected:—SIR JOHN BENSON, JAMES FAIRRIE BLAIR, DARNTON HUTTON, EDWARD JOHNSTON, JOHN KERSHAW, THOMAS EDWARD MILLES MARSH, ROBERT MILLIGAN, RICHARD SMALLMAN, and WILLIAM GEORGE SMART, as Members; HENRY HEATHER BIGG, JOSEPH GORDON, JAMES M'NAIR HARKNESS, RICHARD HODSON, JAMES OLIVER, and JOHN PICKERING, as Associates.

No. 1,039.—"Description of the Loch Ken Viaduct, Portpatrick Railway." By EDWARD LAWRENCE IRELAND BLYTH, M. Inst. C.E.

THIS viaduct carries the Portpatrick Railway across Loch Ken, Kirkcudbrightshire. The loch is about 9 miles long, and has an extreme breadth of about 900 yards. The River Ken flows into it at its northern extremity, and the River Blackwater of Dee, immediately below the site of the viaduct. Both are considerable rivers, liable to sudden and heavy floods, which are principally occasioned by the character of the mountainous and rocky country through which they pass. At times, the water in the loch is raised 10 feet above the summer level. The viaduct crosses the loch at its narrowest part, about the centre of its length, and adjacent to a ferry about 7 miles north of Castle Douglas, one of the termini of the railway. At the site of the viaduct, the loch is about 265 feet wide in summer; but as the viaduct crosses the loch at an oblique angle, the water-way beneath it is increased to about 360 feet. The depth of the water at this part, in summer, is 29 feet, but within 60 yards to the south, it is only 14 feet, and within 100 yards to the north it is 18 feet. The surface level of the country is, however, such, on both sides, that it was found impossible materially to alter the site of the viaduct, or to reduce its obliquity, unless at a great additional expense. From the peculiar construction adopted, this was not important; and the more so, from the fact, that even during the highest floods, there is scarcely any current through the viaduct. The outlet at the south end of the loch, through which the whole flood waters pass, is spanned by Glenlochar Bridge, which has a water-way of 240 feet; while the viaduct has a water-way of 470 feet, and it is situated above the confluence of fully one-half of the waters passing through Glenlochar Bridge. Under these circumstances, it was not deemed necessary to set the piers in the line of the length of the loch; and they are placed at right angles to the viaduct. The line of the viaduct is on a curve of 880 yards radius, and each pair of girders is at a slight angle to the adjoining ones.

The ordinary water-way of the loch is spanned by three wrought-iron girders of the bow-and-string form, each having an opening of 130 feet. On each side, adjoining the abutments, a semicircular arch of 20 feet span is introduced, and the ferry roads are crossed by flat cast-iron girders of 20 feet in length. (Plate 3, Fig 1.)

There is nothing novel about the wing-walls, abutments, or piers of the smaller spans. Good foundations, on gravel, were obtained; and the masonry consists of ashlar facing and bondstones, with slate rubble backing. The foundation of the west abutment of the main spans is also on good gravel; but in that of the east abutment a bed of running sand was met with, which gave some trouble, in pumping and piling for the coffer-dams. The foundation courses in this case were laid on a bed of hydraulic lime concrete, 2 feet in thickness. The two deep-water piers are founded at the depths of 32 feet and 36 feet, on the east and west sides, respectively, below the summer level. Each pier consists of two towers 8 feet in diameter, and 8 feet apart, connected above the water by semicircular arches of masonry, 3 feet in breadth. (Fig. 2.) For each tower a cast-iron tube, 8 feet in diameter, was sunk. The tubes of the east pier were 36 feet deep, and those of the west pier 42 feet deep. They were constructed in lengths of 6 feet, of iron 1⅛ inch in thickness, and were provided with flanges, supplied with iron cement spaces, and made perfectly water-tight. The bottom castings of the tubes had no flange at their lower ends, thus allowing them freely to enter the ground; and for the same reason, the first flange above the bottom was in each case placed on the inside of the tubes. The other flanges were on the outside of the tubes. The upper castings were removed when the masonry was brought up to the surface. Around the piers 4,000 cubic yards of loose rubble stones were deposited, so as to produce an artificially deeper foundation. These stones reach to the height of 24 feet and 28 feet respectively from the foundations.

A staging having been erected across the loch, and four guide and bearing piles driven for each tube, the castings, which weighed about 4 tons each, were fitted together and lowered into their places. Each tube sank, by its own weight, from 1 foot to 2 feet, through silt and clay, finally reaching gravel and sand, which by careful borings, taken previous to the design being made, had been ascertained to form the whole bed of the loch, at this place. On reaching the gravel the tubes remained quite firm, and this formed a good test of the sufficiency of the foundation, as the weight of the tubes, on their narrow edges, was equal to from 8 tons to 9½ tons per square foot, while the total weight on the foundations of the finished structure, including the moving load, is only equal to about 6¼ tons per square foot.

The Author believes, that the method adopted for sinking the tubes to their final depth is novel, and from its perfect success and economy, it deserves notice. Two screw-pans, of the form of an inverted cone, one about 2 feet diameter at the top and 1 foot deep, and the other 1 foot diameter at the top and 1 foot deep, were constructed of plate iron, ¼ inch in thickness, having side openings covered on the inside with leather flaps, to prevent the excavated material from escaping when the pans were filled. From the sides of the screw-pans, there projected three arms of round iron ¾ inch diameter, and about 4 feet long, forged together at the top, and connected by an eye-and-bolt joint to a long shaft, or rod. At the upper end of this rod, there was a four-armed cross-handle, by means of which the screw-pans were worked by four men, and when full were raised by tackle. A slide which passed over the joint at the bottom was lifted, and the pan was tipped and emptied. The larger pan raised about one cubic foot of material each time, and the smaller one about one-fourth of that quantity; but the latter was only used for the harder portions of the excavation. At the bottom of the pans there was a screw-rod, about 1 foot in length. By these means the tubes were sunk at varying rates, the maximum amounting to 18 inches per day, and the minimum, which occurred in the case of the north tube of the west pier, being only 2 inches per day. In sinking this tube, however, a number of boulders were encountered, weighing in some cases 50 lbs. For the purpose of loosening these boulders, a screw-pick was constructed, consisting of a bar of round iron, about 3 feet in length, with circular arms 12 inches in length, projecting from the sides. The boulders, after being loosened by the pick, were raised by the pans. It will be readily understood, that the expense of this apparatus was very trifling; that the principle adopted is that of ordinary well-sinking; and that the excavation was accomplished easily and economically. The Author wishes particularly to direct the attention of Engineers connected with works in India, to this method, as being one that might be employed with advantage, in sinking the brick shafts adopted in that country for foundations.[1]

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[1] *Vide* Minutes of Proceedings Inst. C. E., vol. ii. (1842), p. 64, for a description of the 'miser' for sinking wells, by Mr. James Simpson.—Ed.

When the tubes had been lowered the desired depth, concrete, composed of clean gravel and Portland, or Medina cement, in the proportions of two of gravel to one of cement, was lowered by means of a large pan with a moveable bottom, and deposited to a depth of from 12 feet to 18 feet in each tube. After being allowed from ten days to fourteen days to set, the water was pumped out, and the piers were then completed with solid, freestone ashlar work. The difference in the depth of the concrete in the tubes arose, principally, from the water having entered, in one, or two cases, to such an extent, as to render it impossible to lay the masonry, so that a further quantity of concrete was deposited and allowed to set, before repumping. The four upper courses of ashlar in each pier and abutment are bound together by wrought-iron bars, 4 inches broad and ½ inch thick, of the shape of the pier, and let into the upper bed of each course 12 inches from the face. Strong wrought-iron bolts pass through these courses and bars, and are screwed down at the top. The cordon course is of granite, in large blocks, on which are placed wrought-iron plates, 1 inch in thickness, laid on sheets of vulcanised india-rubber, to diminish the effect of vibration, and on these plates the ends of the girders rest.

The bow-and-string girders are each 136 feet 8 inches in length, and thus extend 3 feet 4 inches on each pier. The form of the bow is segmental, the rise being 17 feet 6 inches, so that the segment is almost identical with a catenary curve, which is the true curve of equal pressure. The sections of the upper and the under booms are identical, and consist of a main plate 24 inches broad and ¾ inch thick, with two channel irons, 8 inches by 4 inches, by ½ inch in section, and placed 8 inches apart, between, and to which, the struts and ties are riveted. The struts and ties are all formed of the same section of channel iron, this being adopted for convenience of construction, though the strains vary. The girders are placed 15 feet 8 inches apart, from centre to centre, giving 13 feet 8 inches clear between the booms, and 15 feet clear between the diagonals.

The transverse girders for carrying the roadway are 6 inches deep at the ends, and 15 inches deep in the centre; the webs are ¼ inch in thickness, and angle-irons, 3 inches, by 3 inches, by ½ inch in section, are attached round the edges, on both sides. These girders rest on the channel-irons of the under booms, each alternate one projecting 2 feet, and from the ends of these, struts of T iron, 4½ inches by 4 inches, by ½ inch in section, are carried up to the points of intersection of the diagonal bracings.

The upper sides of each pair of girders are connected at the centre, and at points 16 feet on each side of the centre, by small girders 12 inches deep. Between these connecting girders there are diagonal lacings of T iron. Cover plates are placed on each side at all the joints; and the shearing surface of the rivets in tension, is equal to the area of section in the under boom, after deducting the space occupied by the rivets. The diagonals are connected together, at their points of intersection, by covering and interior plates, thoroughly riveted, and in respect to the rivets exposed to tension, the rule in the case of the under boom is adopted as the minimum. The rivets are generally $\frac{3}{4}$ inch in diameter, and placed 4 inches apart. The roadway platform is of Memel timber, and consists of longitudinal beams 12 inches, by 8 inches, on the lower side, and 12 inches, by 11 inches, on the higher side of the curve, on which the rails are laid. There are guard beams, 12 inches, by 6 inches, on the inside of each rail, and the planking is 3 inches in thickness; diagonals, 9 inches, by 5 inches, being laid at an angle of 50° to the line of the girders.

	Tons.	Cwt.
The weight of one pair of girders for each span, is . .	49	0
„ of the transverse girders is	14	4
„ of the top girders, resting-plates, and hand-rail is	3	15
Total for one span . . .	66	19
The weight of the roadway, including timber, rails, chairs, and bolts, is	27	0
The weight of the girders and roadway, between the points of support, is . . . . , . . .	88	0
The weight of the ballast, 2 inches deep, is	14	0
Total dead load of	102	0
Rolling load, at one ton per lineal foot	130	0
Total load on one span	232	0

The area of the upper boom, is	33 inches.
„ „ under boom, exclusive of rivets, is .	27·4 „
The distance between the centres of gravity, of the upper and the under booms, is	17·04 „
The tensile strain on the under boom, is . .	4·04 tons per inch.
The compressive strain on the upper boom, is .	3·35 „ „

When the whole of the load is on the girders, there is no compressive strain on any of the diagonals; but there are tensile strains varying from 3·4 tons, to 7·5 tons, or equal respectively to 9 cwt. and 1 ton per square inch of section. With half the rolling load, the greatest amount of compression, in excess of tensile strains, is 1·5 ton, or 4 cwt. per square inch of section, and the greatest amount of tensile strain, in excess of compression, is 7·8 tons, or 1·04 ton per square inch.

The Author considers, that the bow-and-string girder possesses advantages over the Warren, or other lattice girders, with parallel top and bottom members. In the latter class, it is impossible to construct the top and bottom members theoretically correct, without great labour and waste of material. As the bow-and-string girder requires theoretically, a uniform section for the top and the bottom members, there is no waste of material, and the utmost simplicity of construction is attained. The diagonals of the Warren, or other girders of a similar class have a great variation in their strains, and as a matter of economy and lightness, it is necessary to make them of different dimensions, involving, in some cases, great variety in the sections of iron used. In the bow-and-string girder, the variation in the strains through the diagonals is not great, and a uniform section may be used for them, while they also possess the advantage of being much shorter, than in the Warren girder of similar depth. In the Loch Ken Viaduct, the weight of the diagonals of one girder is 6 tons, while the weight of the girder itself is 24 tons 10 cwt.

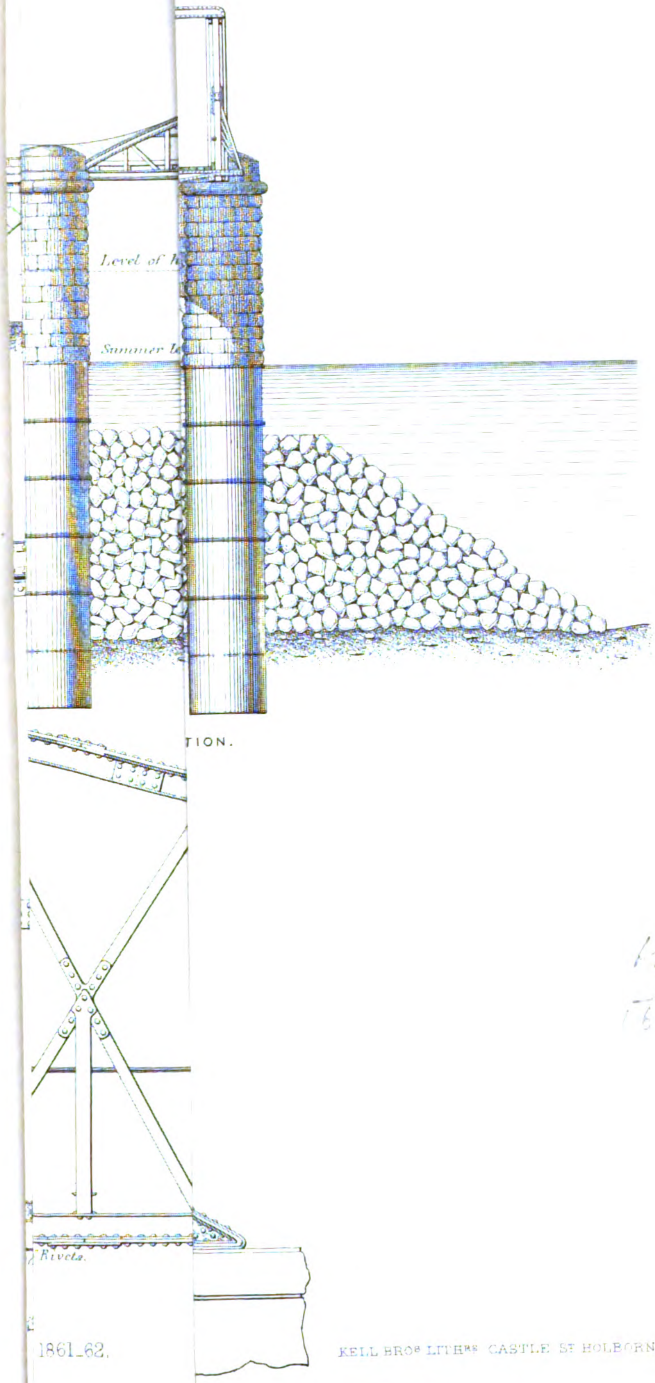
The girders were built in position on the staging, and were kept a few inches above their final level. When each was fully riveted, the slack wedge-blocks, on which it rested, were driven out, and the girder was lowered to its seat on the piers. The levels of each girder were carefully taken at the ends, and at the centre, before and after lowering, and the greatest amount of deflection, which occurred in any girder, from its own weight, amounted to $\frac{3}{8}$ inch. The finished structure was tested by an engine, about 34 tons in weight, being placed stationary in the centre of each span; then being passed over the viaduct at a speed of 10 miles per hour, and again at a speed of 25 miles per hour. The deflection was found to be from $\frac{3}{16}$ inch to $\frac{1}{4}$ inch in each girder, there being no apparent difference in the deflection, whether the engine was stationary, or running.

The girders were finally tested by Captain Tyler, R.E., the Government Inspector, on the 11th February, 1861, with four heavy engines coupled together, giving a weight equal to 1 ton per lineal foot. Each girder was tested three, or four times, and the deflection was observed to amount to from $\frac{1}{2}$ inch, to $\frac{5}{8}$ inch. The transverse girders under the roadway showed a deflection of $\frac{1}{8}$ inch. The vibration in the diagonals, and at the top of the girders, was also carefully and repeatedly observed, and was considered to be quite satisfactory.

The total cost of the viaduct was about £13,000. It was commenced by the contractor, Mr. Thomas Nelson, of Carlisle, in April 1859, and it was entirely finished in October 1860. It is right, however, to state, that there was no necessity for so long a period being occupied in its construction. It could easily have been executed in twelve months, but the contractor was not required to press forward the work, as other portions of the Portpatrick Railway were not to be finished till a later period. The line was opened for public traffic on the 11th March 1861.

The Paper is illustrated by a series of Diagrams, from which Plate 3 has been compiled.

PLATE 3. VOL. XXI.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Mr. G. W. HEMANS remarked, that he was only acquainted with four methods of sinking iron cylinders. In two of those, the water was entirely excluded from the cylinder during the process of sinking. In the other two methods the water was not removed, but the cylinders were sunk, either by means of divers excavating at the bottom, or by some apparatus excavating through the water, in a manner similar to that which had been described in the Paper. The two methods which removed the water entirely, had the advantage of enabling the Engineer to examine the foundations. One of these was generally known as the pneumatic process, in which the water was excluded by the compression of air, as was done in the case of Rochester Bridge, and also in that of the bridge which was being erected by the President, Mr. Hawkshaw, at Londonderry. The other method, was the simple one of pumping the water out of the cylinder, and then excavating the earth from the bottom of it by manual labour. Of the two methods which did not exclude the water, one was that known as Dr. Potts's system. He had tried this in 1850, when building a bridge across the Shannon; but it proved unsuccessful, owing, to the great expense of pumping out the air, and to certain other inconveniences attending it. The bridge was somewhat similar in construction to the viaduct described in the Paper. Its details had been very skilfully elaborated by Messrs. Fox and Henderson, from some slight sketches furnished by himself; and great credit was due to those gentlemen for the able manner in which they had subsequently completed the work, under his directions. It was built for a double line of railway, and had two spans of 165 feet each, and twelve cylinders, each of 10 feet diameter. In the centre there was a swivel bridge, with an opening of 43 feet on each side of the centre pier. The largest cylinders were placed in a depth of water of about 14 feet, and were sunk about the same depth into the bed of the river. In sinking the cylinders on Dr. Potts's system, the cylinder was first erected, and then slightly sunk into the bottom of the river by its own weight. A second and shorter cylinder with a bottom, the whole being of riveted air-tight boiler-plates, was then inserted into the upper part of it. This was technically called 'the doctor.' The upper edges of the doctor were firmly and hermetically cemented to the top of the cylinder. The flexible hose of a powerful air-pump was connected to its cover, and in the bottom there was a valve communicating with the main cylinder. As soon as the air-pumps had created a vacuum in the doctor, the bottom valve was opened, and the air was allowed to enter from the main cylinder. By this means a partial vacuum was created in the main cylinder, and the pressure of the atmosphere caused it to descend. A barometer was attached, to indicate the amount of vacuum. Sometimes, on opening the valves, the cylinder would descend several feet; but generally it sank very slowly, as the amount of exhaustion on no occasion exceeded half a vacuum, and for the most part of the time the air merely leaked in. When some progress had been made in sinking the cylinders by this system, it was ascertained that in certain places there were large boulders under the edges of the cylinders, and that the atmospheric pressure exerted by the machine was insufficient to displace them. The cost of working the air-pumps was also found to be very great. As many as twenty-five men were required to produce the partial vacuum attained. The process had, however, previously been employed in sinking cylinders of small diameter; and in such cases it had proved successful, and, moreover, it was economical; but in the instance which he had described the area on the top of the cylinder was about 80 square feet, and the pressure being only 7 lbs. per square inch, a total pressure of from 40 tons to 50 tons was all that could be obtained. Although the cylinders sank under that pressure, yet it was so slowly, and at so great an expense, that taking into consideration the other difficulties, the process, as before stated, was abandoned, and only three cylinders were sunk by it; the remainder being sunk by pumping out the water, sending men down to the bottom to excavate the foundation, and loading the top of the cylinder with a weight of rails. The bridge was tested with loads of 258 tons to each girder, and with that load the deflection was considerable. He was of opinion that a bow-and-string girder deflected more than a parallel girder of an equal sectional area at the top and the bottom. In the case of the bridge across the Shannon, the deflection under the load of 258 tons was 3 inches. That load was, however, greater than the bridge would have to sustain in practice. The cost of the Shannon Bridge was £30,000. In the case of the Loch Ken Viaduct, the deflection was very small, and the construction firm; but still there were points in which he thought the design might have been improved. It did not appear to have been judicious, that so large an amount of stones should have been deposited round the base of the cylinders. It would have been more economical to have steadied the structure, by sinking a third cylinder in each pier. That would have provided the sub-structure for the future construction of a double line of railway, whereas the stones which had been thrown down would obstruct the subsequent insertion of a third cylinder. Although a bow-and-string girder was economical and proper, in many points of view, yet it was not quite suited to the circumstances in which the Loch Ken Viaduct had been placed. The piers were very high, and narrow, and the entire bridge was situated on a curve, upon which oscillations must take place, whenever a train passed round it at a high velocity. The viaduct would, therefore, have been firmer, and vibration in the structure would have been better prevented, if parallel girders, carefully attached at the ends of the square shoulders over each pier, had been used, instead of the bow-and-string girder.

No. 1,062.—"Description of the Centre Pier of the Saltash Bridge, on the Cornwall Railway, and of the means employed for its Construction." By ROBERT PEARSON BRERETON, M. Inst. C.E.

THE Author having been frequently requested to furnish a description of the means employed for the construction of the centre, or deep-water pier of the Albert Bridge, across the River Tamar at Saltash, on the design and construction of which he was engaged under the late Mr. Brunel (V.P. Inst. C.E.), the Engineer of the Cornwall Railway, has prepared the following narrative:—

In the year 1845, the Cornwall Railway Company applied to Parliament for an Act to construct a Railway from Plymouth to Falmouth. The locality selected for crossing the River Tamar was at the town of Saltash, about 3 miles north of Plymouth, at a place where the river narrows to 1,100 feet wide, with precipitous banks, and has a depth of 70 feet, from the surface of the water to that of the mud.

It was at first proposed, that the bridge should consist of seven openings, one of 250 feet, and six of 100 feet each, of a uniform height of 70 feet; but in consequence of objections raised by parties interested in the navigation, plans were submitted to the Admiralty with the increased dimensions of one span of 255 feet, and six of 105 feet, at a height of 80 feet above high water, all to be built with timber-trussed arches. The Admiralty, however, required that there should be four spans only, two of 300 feet and two of 200 feet each, with straight soffits, and a clear headway above high water of 100 feet. To comply with these requirements, it became necessary to apply to Parliament, for amended powers, which were obtained in 1847.

In selecting the site for the bridge, advantage was taken of a dyke of greenstone trap, which intersects the clay slate formation in the neighbourhood, and crops out to the surface above the water on the Saltash, or western bank of the river. In 1847, a general examination of the bed of the river was made, by borings. It was thus ascertained, that along the eastern side, to beyond the middle of the channel, there was rock, covered with a deposit of mud, or silt from 3 feet to 16 feet in thickness; and that from the middle of the channel the rock fell off rapidly towards the Saltash side. Attempts were made to ascertain, by borings, the figure of the surface of the rock below the silt, in the middle of the river; but owing to the depth of the water and the strength of the current, sufficiently reliable information could not be obtained. It was discovered by divers, that on the Saltash side, the surface of the rock presented a precipitous decline towards the river, but that it was free from chasms, and in the inshore part was favourable for the construction of a pier. In 1848, Mr. Brunel determined on a thorough examination of that part of the bed of the river, where the centre pier would probably be built. This was effected by means of a cylinder of wrought iron, 6 feet diameter, and 85 feet long, which was slung between two gun-brig hulks moored in the river, and the bottom edge of which was lowered a few feet into the mud. Early in 1849, the bed of the river for a space of 50 feet square, had been carefully examined by one hundred and seventy-five borings, made inside the cylinder at the thirty-five different places where it had been pitched. On the last occasion, the cylinder was sunk to the rock, the water was pumped out, to test the water-tightness of the mud, and the material was excavated from the inside. Masonry was then built upon the rock, up to the level of the bed of the river, and the cylinder was withdrawn. From the information thus obtained, an exact model of the surface of the rock, which had been examined, was prepared, showing the irregularities and the fissures that were to be expected.

By this time the construction of wrought-iron railway bridges had become general; and in the cases of the Conway and the Britannia Bridges, spans up to 460 feet had been obtained without difficulty. In determining the dimensions of the bridge at Saltash, it was considered whether it might not, with advantage, be constructed with only one pier in the deep water, instead of three, as would have been necessary for the spans required by the Admiralty; and the experience obtained of the nature of the foundations, having shown that the rock was favourable for the construction of the piers for a span of 465 feet over the western half of the river, designs were made in 1850 for a bridge with two main spans of 465 feet each. In 1852, when it was determined to proceed with the building of the bridge, it was considered practicable to reduce the spans to 455 feet each. The drawings from which the bridge was executed were prepared accordingly, and early in 1853 the work was commenced.

The total length of the bridge, including the adjoining land openings, is 2,200 feet. It has two spans of 455 feet, two of 93 feet, two of 83 feet 6 inches, two of 78 feet, two of 72 feet 6 inches, and nine of 69 feet 6 inches The centre, or deep water pier, which carries the weight of one half of each of the two main spans, consists of a column, or circular pillar, of solid masonry, 35 feet diameter, and 96 feet high from the rock foundation to above high-water mark. Upon this are placed four octagonal columns of cast-iron, 10 feet diameter, carried up to the level of the roadway, which is 100 feet above high-water mark. Upon the tops of these columns, cast-iron standards are fixed, for receiving the ends of the tubes and chains, which constitute the trusses of the bridge. The weight at the bottom of the masonry foundation is about 9½ tons per square foot, increased, when the bridge is loaded by passing trains, to about 10 tons per square foot.

For the construction of the masonry pier, a wrought-iron cylinder, of boiler plates, 37 feet diameter and 90 feet in length, and open at the bottom, was sunk through the mud of the bed of the river to the rock (Plate 4, Figs. 1 to 8). The water was afterwards pumped out, and the mud excavated; the masonry column being built up inside, and the cylinder above the ground being afterwards removed. From the experience obtained in sinking the 6-feet cylinder for making the borings, it was expected that, with the compression of the mud outside the 37-feet cylinder, by a bank thrown round it, after it was sunk to the rock, it would be rendered sufficiently water-tight for the execution of the masonry. But to provide for the contingency of excessive leakage, it was determined, in designing the cylinder, so to construct it as to admit of the application of air pressure in the inside, which had been successfully employed, in sinking the cylinders, for the bridges at Rochester and at Chepstow. The shape of the bottom of the cylinder was obtained, by applying it to a model of the surface of the rock, which had been prepared from the previous borings. This surface, although very irregular and ragged, showed a general dip, of about 6 feet, to the south-west, and the bottom of the cylinder was formed with a corresponding slope, one side being 6 feet longer than the other. A dome, or lower deck, was constructed inside, at the level at which the mud of the river bed would be, when the cylinder was sunk in position; and an internal cylinder, 10 feet in diameter, open at the top and the bottom, connected the dome with the top, or upper deck, of the cylinder. Further to allow of the application of air pressure, the 6-feet cylinder, previously used for boring, was fixed excentrically inside the 10-feet cylinder, and an air-jacket, or gallery, making an inner skin round the bottom edge below the dome, was formed of plates, intended to be used in the roadway girders of the bridge. The air-jacket was about 4 feet in width, divided by partition plates into eleven compartments, or cells, and connected with the bottom of the 6-feet cylinder by an air passage below the dome. It was intended, that the lower part of the cylinder, below the ground, should be filled in with solid masonry, and that it should not be withdrawn. The upper part, 50 feet in length, was constructed in two pieces of larger diameter than the masonry, with vertical separating joints bolted together, so as to be capable of being removed after the completion of the pier.

In the spring of 1853, the cylinder was commenced. It was built upon the beach, or shore of the river, with its lower end towards the water, and with its axis at an inclination of about 1 in 6. It was designed to float at that inclination when empty, and to draw about 15 feet of water forward, as shown in Fig. 4. Whilst the cylinder was being constructed, four wrought-iron pontoons, intended for floating the large spans of the bridge into their places, were moored in the middle of the river, round the intended site of the centre pier, and four mooring anchors and cables were laid out, ready to receive the cylinder.

In May 1854, the cylinder was launched, by being hauled down to low-water mark on launching ways, and it was floated off by the rising tide. It was then towed to the pontoons, and placed between them, and some water was admitted to bring it into its proper position, with the upper deck well out of the water. The mooring chains were taken on board, rove through sheaves, fixed at four points low down in the cylinder, and brought to the purchases on the deck. After the cylinder was secured between the four pontoons, water was gradually let in, till it floated in a vertical position, as represented in Fig. 5. It was then brought to the intended site, and sunk early in June, by gradually admitting water into the inside. The cylinder penetrated about 13 feet through the mud at the bottom of the river, and landing on some irregularities upon the rock, its top heeled over from the vertical, about 7 feet 6 inches towards the east. Preparations were then made for resorting to the use of air pressure, in order to reach the bottom edge, and to bring the cylinder into an upright position. A pneumatic apparatus and air pumps, which had been used at the Chepstow Bridge, were obtained, and fixed to the top of the 6-feet cylinder; two engines of 10 H. P. were placed upon the upper deck to work the air pumps, and two 13-inch water pumps were fixed inside the 10-feet cylinder. Meanwhile, steps were taken for forcing down and righting the cylinder, by water pressure upon the dome, or lower deck, and by loading the higher side with iron ballast. Gravel was thrown down round the cylinder, to secure the surface of the mud from scour, but the quantity was too small to interfere with the 'righting' of the cylinder.

At the end of June, the cylinder forced its way through the obstructions at the bottom edge, and went down 3 feet, taking a nearly upright position. Early in July, the air and water pumps were set to work. In August, the greater part of the mud and oyster shells, which filled the compartments of the air-jacket at the bottom, had been cleared out, and the irregular surface of the rock was being excavated. The water pumps were used for lowering the surface of the water inside the 10-feet cylinder, thereby diminishing the pressure in which the men were obliged to work; the bottom of the cylinder being then 82 feet below the high-water level.

Between August and November, a leak having broken out, through a fissure in the rock on the north-east, or higher edge, great difficulty was experienced, in maintaining sufficient pressure with the air-pumps, to keep the water down, and the bottom dry, for the men to work, while excavating the rock. The leakage was at length considerably reduced, by driving close sheet piling into the fissure.

In February 1855, the cylinder was sunk to its full depth, in an upright position; its bottom being everywhere down to the rock, and 87 feet 6 inches below high water at the lowest place. Before the final dressing of the rock at the bottom, a hemp gasket was worked under the edge of the cylinder, all round the outside, to assist in making it water-tight. The bottom edge, both on the up and on the down stream sides, was also secured to the rock, by lewis bolts, so as to steady it against the action of the current and the tides. In March, the rock was levelled in all the compartments of the air-jacket, and its surface cemented over. The cutting away of the rock was a very tedious operation, as in some parts, as much as 6 feet in depth had to be taken off with chisels, the trap being of such hardness, that tools could with difficulty be got to work it. In April, a ring of granite ashlar masonry was commenced in the air-jacket, and in May, it was completed all round. The granite ring was 4 feet thick, and averaged about 7 feet in height, as shown in Fig. 6. Whilst the masonry was being proceeded with, a bank, about 10 feet high, of heavy material, composed of slag and sand, was thrown round the outside of the cylinder, to compress the mud. The operations with the air-jacket were thus completed, the greatest pressure having been with 86 feet head of water. From thirty to forty men were engaged inside.

Early in June, the air-apparatus was removed from the 6-feet cylinder, the water was pumped out of the body of the cylinder below the dome, and the excavation of the mud had been commenced; but at the end of the month a leak broke out. As the pumps were unable to remove the water, two additional engines and 13-inch pumps were provided, and in the interval, until September, efforts were made to diminish the leakage, with varying success, by throwing more material round the bank outside the cylinder. The leakage, however, continued to such an extent, that even with the two additional pumps, which were got to work in October, the water could not be kept down. In November, it still required the four pumps to keep the water down to 54 feet, in spite of incessant pumping and throwing additional material round the outside. It was therefore thought, that recourse must be had to air pressure in the body of the cylinder below the dome, and preparations for its application were made.

As the 10-feet cylinder, for 50 feet in length at its upper part, was not constructed with plates of sufficient thickness to support, with safety, the pressure when filled with air, a 9-feet cylinder, with thicker plates, and about 50 feet in length, was constructed to be slipped inside, and to be secured at the bottom to the 10-feet cylinder, by a shelf riveted to it, about 50 feet from the top, to which level the four pumps were able to keep the water. Two pairs of new 12-inch air-pumps were provided, in addition to those hitherto used, and commodious wrought-iron air locks, or cages, were constructed, for attaching to the top of the 9-feet cylinder. By the middle of November the shelf was fixed, and the 6-feet cylinder was removed.

To provide against the buoyancy, or upward pressure against the dome and cover of the 9-feet cylinder, it was necessary to load the 37-feet cylinder, in addition to its own weight of 290 tons, with about 750 tons of ballast. Of this about 350 tons consisted of pig iron and kentledge, stacked upon the shelves of the 37-feet cylinder, near the top, and upon cross girders under the upper deck. The remaining 400 tons were placed upon the dome; 100 tons of this consisted of sand in bags lowered through the water, and uniformly distributed, and 300 tons of pig iron, afterwards thrown in upon it. These operations were not completed until the middle of December, when everything was ready for fixing the 9-feet cylinder. The pumps were then brought into good order, and by continued pumping, the water was kept down. The mud was excavated, the cylinder below the dome securely shored across, as shown in Fig. 7, Plate 4, and the rock levelled. The masonry in the body of the cylinder was commenced early in January 1856. A leak was discovered to have again broken out at the same fissure as before, and it had torn away the rock underneath the masonry of the air-jacket and the bottom edge of the cylinder; but the masonry itself was not disturbed.

As soon as the rock was reached, holding-down lewis bolts were let into it, with ironbars to be built into the masonry, and attached to the bottom of the 10-feet cylinder, as a further precaution in case of any sudden influx of water. The water from the leak, and from some smaller fissures, was carefully collected in pipes, and conveyed to two cast-iron wells, which were formed in halves and placed round the suctions of the water-pumps, the whole being then built into the solid masonry.

By incessant pumping, the water was kept down, so that by the end of February, the masonry, in thin courses of granite ashlar in cement, had reached the level of the air-jacket ring. The masonry was then thoroughly bonded together, the plates of the air-jacket being cut out as it proceeded. Upon the top of the bonding-course, two courses of hard brickwork in cement were laid, making a perfectly water-tight floor over the whole surface of the section, which was there 35 feet in diameter. Meanwhile, the masonry of the air-jacket, where the leak occurred, was taken down, and the leak was diminished by additional sheet piling at the edge of the cylinder, so that one engine and pump could be dispensed with. The water was collected in a pipe having a sluice valve, which on being closed early in March reduced the leakage by about one third. In the middle of March the water was drawn off above the dome, the ballast was removed, and the 37-feet cylinder above it properly shored. Early in April, the masonry had reached the springing level of the dome, or 20 feet in height. The dome was then cut away, as well as the bottom of the 10-feet cylinder. Two pumps were now sufficient to keep the water down.

By the middle of April, one of the pump-wells was filled up with cement concrete. Early in June, one pump was found sufficient to keep the water down, the masonry being 43 feet high, and proceeding at from 5 feet to 7 feet in height per week. In the middle of June, the masonry being then 46 feet in height, the influx of water was entirely stopped, by filling the remaining pump-well with cement concrete, and closing the top of it.

The masonry was completed to the top of the plinth, or cap of the pier, by the end of October; and in the middle of November, the upper part of the cylinder was unbolted, at the separating joints, and floated to the shore with the pontoons, and the iron made use of, for the decking of the pontoons which were to be used in floating the bridge.

All that then remained to be done, was to fix the bases of the cast-iron columns to the masonry, and to erect the columns themselves for receiving the ends of the bridge when floated into its place. This was accomplished, with the first span, over the western half of the river, in September, 1857; and with the second, or eastern half, in July, 1858.

The Paper is illustrated by a series of diagrams from which Plate 4 has been compiled.

[Mr. Brereton

Fig: 4

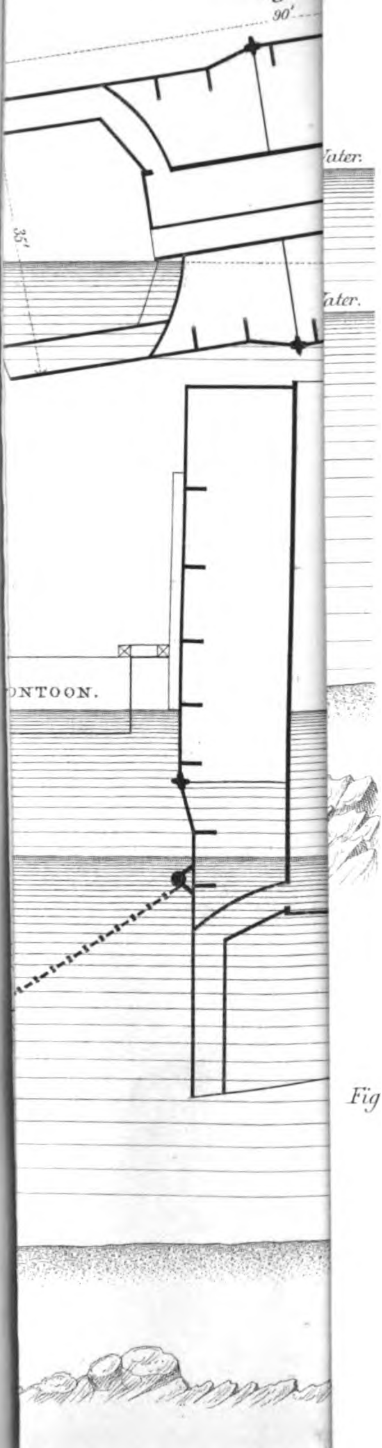
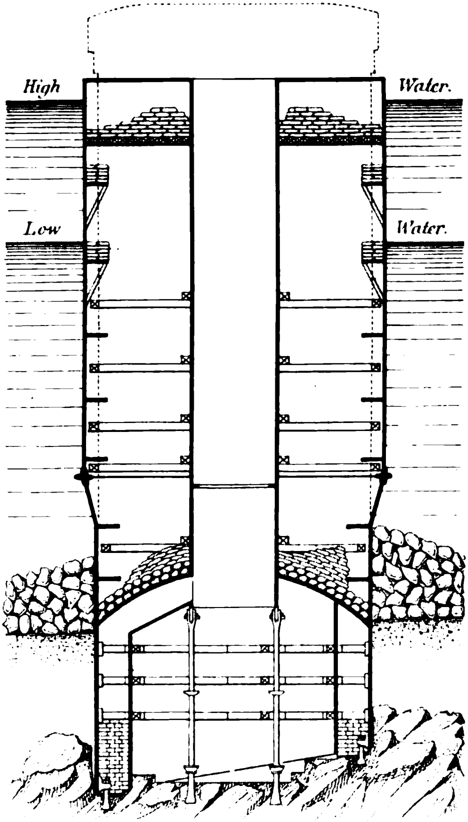
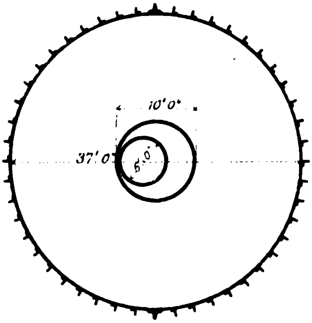

90'
35'
Water.
Water.
ONTOON.

Fig: 7.


High
Water.
Low
Water.

Fig^s 8.



PLAN ABOVE DOME.

KELL BROS LITHRS CASTLE ST H

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Mr. BRERETON begged it might be clearly understood, that it was not intended to claim for the means employed, for the construction of the centre pier of the Saltash Bridge, any particular advantages, over any other system which might have been adopted for a similar purpose. Nor did he desire to provoke any discussion upon it, but would be happy to render the description of the work complete by any further information that might be asked for.

Mr. JOHN COCHRANE remarked, that the system which had been described in the Paper, although applied on a larger scale, was identical in principle with that which the late Mr. Brunel had previously used in the construction of the bridge across the Wye, at Chepstow, on the South Wales Railway. The plan employed was no doubt a good and efficient one, but in sinking cylinders of large diameter, it was not an easy task to apply the weight, which was required to assist the pressure of the air. He could not, however, understand, why there had been so much difficulty in keeping the cylinders free from water, unless the water proceeded from springs, having their source in the adjacent hills, and in consequence entered the cylinder at a greater pressure than that which was employed to keep it out.

Mr. FREDERICK LAWRENCE thought it probable, that a great portion of the difficulty of keeping the cylinder dry had arisen from the fact, of the bottom of the cylinder being formed to suit the irregular surface of the rock. One side being thus 6 feet higher than the other, it was very much like a diving-bell tilted on one side. It would be difficult otherwise to account for the unsuccessful application of the great pressure employed.

Mr. BRERETON, in reply, drew attention to the fact, that there was an extensive surface of riveted boiler plate to keep free from air-leakage. It was therefore not easy, in a cylinder of 37 feet diameter, to keep up a constant pressure of 40 lbs. to the inch, and to provide air for thirty men, or forty men inside, without much waste and leakage. There were double 12-inch air-pumps, but being kept constantly at work, they were frequently out of order. If a greater number of pumps, in relays, had been employed in the first instance, the trouble might have been diminished, but in consequence of the thinness of the boiler-plates of the air-jacket, there was great difficulty in keeping the caulking air-tight. The air escaped through the caulking, and round the rivet-heads, and penetrated through the hard-wood planking with the greatest ease, unless it was covered with clay, or slime as a preventive to leakage. The intermittent pressure against the cylinder, also interfered with the absolute tightness of the joints, and it no doubt contributed largely to the leakage. The air-pressure was equal to a height of 86 feet, or 88 feet of water, or about 40 lbs. to the square inch.

There was a difference in level of only 6 feet in the bottom of the cylinder, and almost all the water leakage came from the higher side of the bevelled edge. It was the water from that side which occasioned the most trouble.

At first some inconvenience was experienced by the men, in working under great pressure, and at the commencement of the work they stayed in too long at one time. He had remained seven hours at the bottom, with some of the men. After coming out they were slightly paralysed, but in two, or three days they quite recovered. With three-hour shifts, the men could remain at work for several months consecutively.

The weight of the cylinder, including the dome, intermediate cylinders, shelves, &c., was about 290 tons. The bottom was composed of double plates, $\frac{1}{2}$-inch in thickness, and the top, of single plates $\frac{3}{8}$-inch in thickness, with T irons outside, and shelves and angle-irons inside.

Mr. HAWKSHAW, President, said, that the Institution was under great obligations to the Author of the Paper, for the interesting details of a work of magnitude and difficulty. The system employed was of the greatest aid in engineering works, and was capable of very extended application. There was considerable difference in the relative ability of different men to sustain the labour under air-pressure. For instance, he had found Irish workmen less able to stand the pressure than Englishmen. He attributed that to the better mode of living and more robust frame of the English workman. He was sorry to say that, in the works under his charge at Londonderry, there had been some casualties. The men employed had to bear a pressure of 75 feet, or two atmospheres. One of the effects produced by that amount of air-pressure was, that the joints of some of the less robust men began to swell. He, however, knew one man, who although he had followed the occupation of a diver for about twelve years, seemed as comfortable under the water as he was upon land. But such cases were the exceptions.

If the Author would complete the Paper, by giving an account of the manner in which the superstructure of the Saltash Bridge had been erected, he would confer a further benefit upon the profession, and would contribute a valuable addition to the records of the Institution.

March 11, 1862.

JOHN HAWKSHAW, President,
in the Chair.

No. 1,061.—"Description of the Delta of the Danube, and of the Works, recently executed, at the Sulina Mouth."[1] By CHARLES AUGUSTUS HARTLEY,[2] M. Inst. C.E.

IN the autumn of 1856, by virtue of the treaty of Paris, a commission was constituted, which was styled "The European Commission of the Danube." It consisted of the following delegates, from each of the seven contracting powers:—from Austria, the Chevalier de Becke,—England, Major Stokes, R.E.,—France, Monsieur Engelhardt,—Prussia, Herr Bitter,—Russia, Baron D'Offenburg,—Sardinia, Marquis D'Aste,—and from Turkey, Omer Fetzi Pasha (President). It was charged "to designate, and to cause to be executed, the works necessary, below Isaktcha, to clear the mouths of the Danube, and the neighbouring parts of the sea, from the sands and other impediments which obstructed them, so as to put that part of the river, and the said parts of the sea, in the best possible state for navigation;" and in order to cover the expenses of the necessary works, the Commission was authorised to fix, and to levy duties, of a suitable rate, on the express condition, that in this respect, as in every other, the flags of all nations, should be treated on a footing of perfect equality.

The Commission, at the commencement of its labours, appointed the Author Engineer-in-chief, and he has acted in that capacity up to the present time. In the spring and summer of 1857, he was engaged with the engineering staff, in making preliminary studies, of each of the three principal branches and mouths of the Danube, with a view to report on their respective capacities for permanent improvement. In the execution of this task, he was greatly aided by the possession of the admirable surveys of Capt. Spratt, R.N., C.B., several copies of whose plans had been presented to the Commission by the British Government, and which, as affording a correct basis for projected works of improvement, were found to be very valuable. The Author will now take advantage of these charts (Plate 5), and of his own investigations, to briefly describe the chief characteristics of the progress of the river through its delta.

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[1] The discussion upon this Paper extended over portions of two evenings, but an abstract of the whole is given consecutively.

[2] The Author subsequently received the honour of knighthood.

The Danube after a course of 1,700 miles, during which it receives more than four hundred tributaries, and drains upwards of 300,000 square miles of country, passes the Bulgarian town of Isaktcha—the inland limit of the Commissioners' jurisdiction—in a single channel 1,700 feet in breadth, and 50 feet in depth. Isaktcha is situated on the right bank, at a distance of 40 English miles below the large corn-exporting port of Ibraila, and 30 miles below the equally large corn-exporting port of Galatz. Isaktcha is 76 miles from the sea, following the course of the Kilia branch of the Danube; 78 miles by the Sulina branch; 90 miles by the St. George branch; and 58 miles from the sea in a straight line.

At 15 miles below Isaktcha the head of the Delta is reached, at a spot called Ismaïl 'Chatal,' or Fork, and it is here, that the fresh waters first divide, never to reunite; as seventeen twenty-sevenths of their volume pass onward in an easterly direction by the Kilia branch, and the remaining ten twenty-sevenths take a south-easterly direction by the Toulcha branch.

The Kilia maintains a wide and deep channel for 12 miles N.E. of the chatal to the town of Ismaïl, whence a communication by water exists with Lake Yalpuc, at the upper end of which is the frontier town of Bolgrad. Ismaïl occupies a fine situation on the left bank, but it is of slight commercial importance. Its once-famous fort was totally destroyed, soon after the conclusion of the Crimean war. From Ismaïl the Kilia trends, for about 8 miles, in a S.E. direction, to a bend which directs the waters again to the N.E. Soon afterwards the river is divided into three branches, all of which maintain a navigable depth. These meet together again at Staroi-Kilia, at about 2 miles below the town of Kilia, and 44 miles from the chatal. Down to this point the greater portion of the left bank of the Kilia forms the southern boundary of the great Russian Steppe, and is raised far above the level of inundation. It is only here that it assumes the character of the opposite bank, which is liable to be flooded, throughout its entire length, during times of extraordinary high water. At 5 miles below Staroi-Kilia, the river again separates into three branches, which, after a course of about 12 miles, once more unite, and flow in a single channel, for 4 miles further, to the large basin of Vilkovi, situated at 4 miles from the N.E. angle of the delta. Between this basin and the chatal, the course of the Kilia, although often separated by numerous islands, continues to preserve, in all its different channels, between well-fixed banks, a sufficient navigable depth for ships of the largest burden. Below this point, however, these advantages are lost, for the Vilkovi basin is the root of a branch called the Stambul, which withdraws to the S.E., through swampy ground, half of the volume of the Kilia; of the Ochakof, which bears to the N.E., one-fourth its volume; and of three other branches, one to the left of the Ochakof, and the other two to the right, which absorb the remainder. These five branches, moreover, afterwards split into smaller channels, so that finally the waters of the Kilia are delivered to the sea, by at least twelve distinct mouths, not one of which is navigable, except for fishing-vessels.

At 11 miles below Ismaïl Chatal, the Toulcha branch separates into two channels—the St. George, and the Sulina. This point is called the St. George Chatal.

The course of the St. George is generally in a S.E. direction; it bears with it four-fifths of the waters of the Toulcha branch, or eight twenty-sevenths of the volume of the main river at Isaktcha; its average width is 1,200 feet, and at seasons of extreme low water, the depth of its navigable channel is nowhere less than 16 feet. At 2 miles from its chatal, the St. George commences to skirt the foot of the Besh-Tepeh hills, with which it continues parallel for about 10 miles. It then quits its hitherto nearly straight course, and commences the first of a series of windings, for which its central and lower portions are remarkable. From the ample and uniform width and depth of the river, however, these windings are not such obstacles to the navigation as might be supposed. At 29 miles from the St. George Chatal, a small stream, called the Donavitza, branches off from the right bank, and after a long and tortuous course, communicates with the vast shallows of the salt water lake of Raselm. This lake is connected with the Black Sea, by a small channel called the Portiza, the mouth of which is barely navigable for small boats. Owing to this separate outlet to the sea, the Donavitza has been termed, by some writers, a branch of the Danube, but its insignificant section, of less than 50 square yards, by no means entitles it to such an appellation. At the small hamlet of Galinovak, 42 miles from the chatal, such a very sharp bend of the river is encountered, that a cutting of only 1,700 feet in length, through the narrow neck of land separating its two parallel reaches, would shorten the course of the river full 3 miles.[1] Hence the river continues, with a broad and deep and less tortuous course, to the upper Olinka Island, where it separates into the branches of Kedrilles and Olinka, the former of which delivers almost immediately to the sea, in an E. direction, by a channel across the bar varying in depth from 5½ feet to 8½ feet, two-thirds of the volume of the St. George; while the Olinka channel carries off the remaining third, which is soon spread over the shallows that extend for some miles to the south of the Olinka Islands.

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[1] By cutting three new channels, of an aggregate length of 6 miles, at its worst bends, the length of the St. George branch would be reduced 17 miles. At present it is only proposed to execute the above-mentioned cutting at Galinovak.

The general direction of the course of the Sulina is to the east. It abstracts one-fifth of the waters of the Toulcha branch, or two twenty-sevenths of the volume of the main river, and its navigable width is rarely more than 300 feet. Between the St. George Chatal and the port of Sulina, there are nine shoals, the depth over which, during seasons of low water, varies from 10 feet to 14 feet; although throughout the spring and early summer, when the waters are high, there is a depth of at least 16 feet over a width of 300 feet. The entrance to the Sulina branch is of difficult navigation, owing to the acute angle which it makes with the Toulcha, and also on account of the sand banks formed by the counter-action of the current, which, in entering the Sulina, is opposed in direction to the parent stream. These obstacles, combined with the many intricate windings, and the numerous shallows which occur in the upper portion of this branch, render the navigation of the Sulina at all times hazardous and difficult. It is not until the extraordinary sinuosity known by the name of the letter M, has been passed, and the last shoal, situated at 30 miles below the St. George Chatal, has been avoided, that the anxious mariner feels secure of a safe course, for the remainder of his downward voyage. For the last 22 miles, the Sulina maintains a good navigable passage to the sea, which is reached at 52 miles from the St. George Chatal, or at 63 miles from the Chatal of Ismaïl.

The Delta proper of the Danube may be briefly described as being bounded on the north by the Kilia branch, on the south by the Toulcha and the St. George branches, and on the east by the Black Sea. The enclosed space, which comprises an area of 1,000 square miles, is a triangular piece of land, of which the Ismaïl Chatal is the western apex, and the sea coast, extending from the mouths of the St. George to those of the Kilia, the base.[1] The Delta, with the exception of a few patches of cultivation on the borders of the St. George and Kilia branches, is entirely destitute of culture. Reeds of large growth cover the greater portion of its surface, and vast swamps and fresh-water lakes are met with in every direction. On each of the islands of St. George and Leti, to the north and south of the Sulina, there is a large natural forest of oaks, many of which are 3 feet in diameter, and belts of willow and alder trees clothe the convex shore of the St. George, at every bend of its course. The population of the Delta does not exceed 6,000 souls, and is chiefly composed of Greeks and Russians, although since the Crimean war, all the islands of the Delta below Isaktcha have been in the possession of Turkey. The soil of these islands is composed of finely-comminuted alluvions, and is entirely free from stones, gravel, or even coarse-grained sand. During extraordinary high floods, the Delta, being unprovided with artificial banks, to contain the swollen waters, is almost entirely submerged, whilst at seasons of drought, its banks are elevated from 10 feet to 12 feet above the level of the river at the Ismaïl Chatal, and from 8 feet to 10 feet, at the chatal of St. George. In the lower reaches of each of the three branches, the level of the river is but little affected by variations of the upland waters. Adjacent to the mouths, it never varies more than one foot, except when influenced by the wind. During high floods, the inclination of the surface water of the Sulina branch is 3 inches per mile, but during extreme low water, it does not exceed 1 inch per mile. The surface of the ground at Ismaïl Chatal, is 19 feet above the level of the sea, and as the distance from that point, in a straight line, to the sea coast is 45 miles, the inclination of the Delta seaward is about 5 inches per mile. Along the seaboard, the shore is rarely more than 2 feet above the mean sea-level; near the St. George mouth, however, there is a long stretch of sand hills from 8 feet to 10 feet in height, and adjoining the Stambul mouth of the Kilia, are to be found, dunes having an altitude of from 40 feet to 50 feet.

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[1] If, however, the island of Dranova, to the south of the St. George branch, be added, to what has been called the Delta Proper—and in formation the Dranova island is identical with the islands to the right and left of the Sulina—then the entire extent of Delta land is about 1,300 square miles.

During ordinary high water, when the current has attained a velocity of from 2½ miles to 3 miles per hour, the Danube, before it divides at Ismaïl Chatal, delivers a volume of water equal to 19½ millions cubic feet per minute, while during the dry season, when the current has been reduced to less than 1 mile per hour, the flow does not exceed 7½ millions cubic feet per minute. At times of extraordinary floods, such as occurred in March, 1861, the velocity is increased to 5 miles per hour, and the volume of water then delivered by the Danube to the sea, was equal to 60 millions cubic feet per minute, or eight times the quantity discharged at ordinary low water.

Great care has been taken to ascertain, as nearly as possible, the comparative amount of deposit held in suspension during ordinary summer floods, and when the river has fallen to its low-water level. These results will probably be published in detail hereafter. At present it is sufficient to state, that when the waters are most surcharged, they bear to the sea as much sedimentary matter as would—supposing it to be solidified into coherent earth—be equivalent to a deposit of 1 inch to 1 cubic foot of water; and, that not more than one-fortieth part of this proportion is transported when the floods have subsided. Thus, at the former period, upwards of 600,000 cubic yards of diluvial detritus pass into the sea, by the several mouths of the river in twenty-four hours, and at the latter period not more than 15,000 cubic yards.

The results of these investigations account, in a great degree, for the changes which take place, from time to time, in the position and extent of the sand banks forming the bars across the several mouths of the river. At times of high floods, these bars are further from the shore, their magnitude is considerably increased, and the depths over them are diminished. Thus the effect of a flood current, surcharged with earthy matter, is first of all by its quickened speed to deepen the channel over the bar. The displaced portion is then pushed out into the shallows beyond, and there the river current, checked by the nearly stationary waters of the sea, precipitates the heavier particles of the matter held in suspension to form a new bar; while the lighter particles are carried further, and widely distributed over the sea depths beyond. The accuracy of this theory is further supported by the fact, which is well known to all the most experienced pilots on the river, that during times of inundation from the upland waters, the bars are not only shallower, and further removed from the shore, but they are also encrusted with hard sand, which yields with the greatest difficulty to the ploughing action of a vessel's keel. This stratum of sand is undoubtedly of river origin, and evidently owes its freedom from impurity, to the sifting and cleansing process exercised upon it by the waves during stormy weather. The distance, and the height, at which the new bar is formed, are of course much influenced by the direction of the winds, that happen to prevail at the time of the floods. If the floods are accompanied by westerly winds, the bar will be further out to sea, but less considerable, than if the flood waters were met by a strong opposing east wind. As soon as the floods subside, the effect produced by the strong current ceases, the new formations are gradually pared down by the ground waves; the alluvium of the river is precipitated nearer the shore, and the bars, by degrees, rèsume their old position with regard to the shore line; which they retain until the advent of another flood causes the same process to be repeated. The deposits which form the bars, although stretching across the mouths in every case, extend only a short distance to the north, but to a very considerable distance towards the south. This effect is produced by the combined influence of the prevailing northerly winds and of the littoral current, which latter during these winds, and in calm weather, constantly flows towards the Bosphorus.

There are no tides in the Black Sea, and the level of the water along the coast of the Delta is solely influenced by the opposing action of the land and sea winds. Thus, when the westerly wind blows violently, the sea falls 18 inches below its mean level, and when strong easterly winds prevail, it rises 2 feet above the same point. The north-east winds are the strongest, and blowing over comparatively shallow water, they produce the most dangerous seas. The largest waves are, however, those raised by the south-east gales, which cross a reach of 500 miles. (Plate 5; sketch map of Black Sea.)

The sea depths, opposite the Delta, decrease to the north: thus opposite the St. George mouth, at 3 miles from the land, the sounding line gives 16 fathoms, whereas at the same distance from the Sulina and the Kilia mouths, it gives but 10 fathoms. The sea slope, immediately in front of the Kilia delta coast line, is still more gradual, although from the actual bars of the Kilia, the bottom rapidly shelves off into deep water. The distance, however, of the bars from the shore, the rapid advance of the shelf seawards, and the large volume of water delivered to the sea, by so many mouths branching out in all directions, all tend to place the mouths of the Kilia in the worst possible condition for successful treatment.

The Author instituted a careful comparison of the two accurate and minute surveys of the Kilia, the one made by the Russian Government in 1830, and the other by the English Government in 1856, from which it appeared, that during the interval the shallows at its entrance advanced fully one mile, in the direction of the Sulina mouth. This startling extension, in so short a period, the uncertain and changeable nature of the many branches issuing from the Vilkovi basin to the sea, and the distance of the bars from the shore, were the chief considerations which induced the Author to form an unfavourable opinion of the Kilia, in spite of its possessing the best river channel. He therefore recommended in preference, the improvement either of the St. George, or of the Sulina, where the sea depths are greater, and the advance of the sand banks much less remarkable.

In comparing the merits of the two latter branches, for the permanent improvement of each of which the Author prepared projects in the autumn of 1857, he arrived at the conclusion, that nearly in every respect, the St. George offered decided advantages over the Sulina. After the short description which has been given of their respective channels, it need not be said, that the river portion of the St. George offers no real obstacles, whilst at every turn of the upper reaches of the Sulina, disaster of every kind is imminent. It is true, that in order to reach the Kedrilles bar of the St. George, double the length of works would be necessary, and that, consequently, in the first instance, the additional expense would be in the same proportion; but it is no less true, that if the sand banks were once passed by such works, the greater sea depths opposite the St. George, would insure for a much longer period, a constant navigable depth at the sea entrance. The St. George mouth is not only situated at the salient angle of the Delta, and therefore the most favourably placed, for the beneficial action of the littoral current, but, it is the easiest to reach, and is nearer by 18 nautical miles to the Bosphorus than the Sulina. It is also the most favourably situated with regard to the safe manœuvring of vessels, during N.N.E. winds; as the trend of the coast towards the Portiza mouth gives more sea room, and enables vessels, if caught in a northerly gale outside, to run for shelter, under the lee of the S.W. shore of the Delta.

When the Author presented his first projects, the Commission had before it three other designs, by three eminent technical authorities who had visited the ground, each of whom advocated the adoption of a different branch. The authors of these several reports, differed widely in their estimates of the merits of the three principal branches and mouths, and of the difficulties to be overcome, in rendering them navigable for large vessels. In one respect alone all were agreed, and that was, in recommending that whichever mouth were chosen, the system of improvement should be that of guiding the river waters across the bar, by means of piers projected from the most advanced dry angles of the mouth; or, in other words, that of concentrating the strength of the river current, on the bottom of the proposed improved seaward channel, by an artificial prolongation of the river banks into deep water.

In the midst of so many conflicting opinions, as to the best branch to improve permanently, the English, French, Prussian and Sardinian Governments referred the whole question to the decision of two military and two civil Engineers, the former delegated by England and Sardinia, and the latter by France and Prussia. But this measure, instead of leading to a satisfactory solution, only complicated matters still more; for these gentlemen when assembled together at Paris, prepared a very able and elaborate report, in which they recommended the choice of the St. George branch, with a sea entry and gates independent of the mouth; a project diametrically opposed in principle to the system of improvement, previously proposed, by all the naval and engineering authorities, who had visited the several mouths of the Danube, and had studied their peculiarities on the spot.

In the meantime, the merchants of Galatz and Ibraila called loudly for some immediate improvement of the Sulina, the only navigable branch to the sea, and urged that the heavy iron rake, which, it was alleged, had formerly been so usefully employed by the Turks in deepening the Sulina Bar, should be again applied for the same purpose.[1] In order to satisfy these demands, and to test the value of a means so simple, and comparatively so inexpensive, the Commission not only caused the old Turkish rake to be dragged across the bar fifty times a day by a steamer, during three of the finest months of the year, but they also employed, during the same period, a steam dredger, capable of lifting 1,000 tons per day, to turn over the bottom of the bar, with a view to enable the river current to transport the disturbed material into deep water. Now, precisely because this current was too feeble, and did not possess the transporting force required, these palliative measures failed to produce any appreciable beneficial effect; and the Commission therefore, after having given the system a fair trial, abandoned it entirely. The Author considering that, from motives of expediency, it might be deemed desirable to select the Sulina branch definitively, in preference to the St. George branch, had previously prepared an alternative design for permanent works at the entrance of the Sulina; and the Commission, on relinquishing the operations above described, resolved to improve the channel across the bar of that branch by means of guiding piers of a temporary character, but carried out on the lines which the Author had designed for the permanent works. The Commission arrived at this decision with the view of giving the speediest relief to the navigation, in the cheapest manner. But it was distinctly guaranteed that this provisional expedient should not prejudice the choice of the mouth, to be eventually selected for permanent treatment.

The original design for the permanent works at the Sulina mouth, may be thus briefly described. The piers were projected to cross the bar, and to terminate in a depth of 18 feet, in order, in the first instance, that the proposed channel might be deepened by the concentrated action of the river current, and that afterwards a good navigable channel should be maintained beyond the piers; it being assumed, that when the troubled waters of the river were brought into immediate contact with the littoral current crossing the pier heads, the fluvial matter would remain suspended until it was far removed from the entrance. With this object in view, the north pier was designed to be 5,850 feet in length, and the south pier 4,310 feet; their general direction to be E. by N., so as to shelter the port, and to allow vessels to enter during every on-shore wind. They were to be constructed of 'pierre perdue,' surmounted by solid masonry and ashlar work, carried up to 6 feet above the water line; and their estimated cost was £300,000, or at the rate of £30 per lineal foot. The south pier was designed to be considerably shorter than the north pier, for two reasons; first, it was considered unnecessary, and indeed undesirable, owing to the configuration of the coast, that the piers should run parallel to each other until the bar was reached; and advantage was therefore taken of the projection of the south lip, beyond the opposite shore, to commence the south pier, from a point nearly 1,000 feet seaward of the commencement of the north pier; secondly, in order to shelter vessels entering and leaving the harbour, during the prevailing N. and N.E. winds, the north pier was designed to overlap the south pier 600 feet, a length equal to the normal width of the river, and also to the space between the piers where their parallelism commenced. Such was the first design, and as the second only differed from it in the length of the piers, and in their comparatively provisional character, reference need now only be made to these differences, without further allusion to the actual trace of the works, which was identical in both cases.

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[1] It has frequently been stated by writers on the Danube, that either by the use of a rake, or by means of a slight palisading of timber, or by both combined, the Turks formerly maintained a depth of 16 feet over the Sulina bar. The Danube Commission made every effort, but in vain, to obtain a reliable record which would place the truth of such statements beyond a doubt. The Author is of opinion, that no essential improvement was ever obtained by the means above described, and that the depth of the Sulina bar channel, prior to the labours of the Commission, never exceeded 12 feet, whilst it frequently fell below 8 feet.

The Author, having received the instructions of the Commission in the sense above referred to, proceeded to design works of a minimum section with regard to strength, in order to prolong the piers as far seaward as possible, for the smallest sum, and with the greatest speed. The problem submitted to him was to provide guiding works, which, for the expenditure of a sum, limited to £80,000, should be carried out sufficiently far to give an increased depth of at least 2 feet, and should have sufficient solidity, to resist uninjured the attacks of a notoriously tempestuous sea, for a period of from six years to eight years. This duration of time was based on the assumption, that during such an interval either the St. George would be opened, or it might be considered expedient to limit the improvement of the Danube, to rendering permanent the provisional works already executed at the Sulina.

The first idea which naturally presents itself to the mind, in designing moles such as those last described, in a country where stone is obtainable, and where skilled labour is only to be had at great cost, is the simple expedient of throwing down rough stones, at random, along the line of the projected works. On consideration, however, the following objections to this plan caused the Author to reject it. First, if carried above the surface of the water, the upper stones would be liable to constant displacement during gales, and the cost of such a mass of material, consisting chiefly of first-class rubble, brought from a distance of 60 miles, would greatly exceed the limits of the proposed expenditure.

Secondly, supposing the stones to be only carried up to within 3 feet, or 4 feet of the surface of the water—a plan actually proposed to the Commission by one of its technical advisers—the piers would form dangerous submarine reefs, on each side of the entrance, and the escape of the water issuing from the river over these reefs would greatly diminish the good effect sought. It thus appearing that the employment of stone by itself, would not answer the requirements, the Author turned his attention to the employment of fir timber, which on the Danube can be purchased in any quantity, and of any size, at from threepence to fourpence per cubic foot. He then found, that by combining timber with third-class rubble, he could construct the required length of piers for a sum not exceeding the prescribed limits.

The first plan was to construct strong cribs from 30 feet to 60 feet long, built with timbers 12 inches square, firmly fastened together; to load them with stones, and to sink them at intervals of 20 feet along the line of works; filling in between with close and open piling, driven from staging supported by the cribs; the whole being protected at the foot by rubble stones. In practice, however, this plan was not adopted, for the cost of the cribs, owing to the difficulty of fixing them, and afterwards to their settlement in the sand, would have exceeded the original estimate. Choice was finally made of a structure composed of piling and 'pierre perdue,' surmounted by a timber platform 14 feet wide, strengthened occasionally by solidly-constructed cribs of the same width (Plate 9).

The works were commenced on the 21st April, 1858, and an account will now be given of the system of execution. A temporary staging fixed on piles, driven by ringing engines, worked from barges, was run out from 200 feet to 300 feet in advance of the permanent piling; and although, during the progress of the work, it was several times partially destroyed by the violence of heavy gales, the repairs were easily and rapidly effected during fine weather. This staging supported nine crab engines, each working a monkey weighing 15 cwts., and driving down daily, on an average, a pile 13 inches square, 16 feet into the hard fine sand of which the bottom is composed. By these means three rows of three piles each, at equal distances apart of 7 feet, were frequently driven in one day. They were then immediately secured by double longitudinal walings 12 inches by 6 inches, and double cross ties, 12 inches by 4 inches, and 15 feet long, the whole being surmounted, by two trampieces 6 inches thick, and planking 3 inches in thickness, at 4 feet above the level of the sea. From this permanent platform, the close piling on the side next the sea was driven, by six similar crab engines, following closely on the open 7 feet bays in advance. The daily rate of progress during fine weather was 20 feet; and no sooner had this length of sheet piles been placed, than stones were thrown down, to protect its footing in the sand, which, without such protection, was liable to be washed away to such an extent by the beat of the sea, as to endanger the stability of the exposed close piling, although driven 14 feet into the ground. This scouring action of the sea was the only real difficulty to contend against; and so serious did it become, when the skirt of the bar was reached, along the line of open piling immediately beyond the sheeting, that although confined to that locality, it threatened at one time to demand for the completion of the works double the quantity of stone originally estimated.

As an instance of the power of this action—the result solely of attacks from the sea, unassisted by the river current, and of the incompressibility of the foundation,—it may be mentioned, that a crib, 30 feet by 15 feet, sunk in position in a depth of 9 feet of water, and loaded with 130 tons of stone—the weight of which, owing to the crib's false bottom, was entirely supported by the ten square yards of foundation under the lowest course of framework— remained for nearly one week without settling down the $\frac{1}{100}$th part of an inch. No sooner, however, was the foundation attacked by a heavy sea, than the crib sank bodily 4 feet in three days, and it then only came to a bearing owing to the stonework, which in the meantime had been deposited round it almost to the level of the water, having arrested the scour. In the first instance bags of sand were made use of, to fix the bottom, and to fill the holes which had been scoured out between the open piling. This expedient was economical, as long as old sacks were supplied at a merely nominal price; but when the supply failed, and the cheapest kind of new canvas sewn into sacks was substituted, it was found that, bulk for bulk, the sandbags cost as much as stone, without answering the purpose as well. Thereupon the following plan was adopted, for a length of about 400 feet. Long rafts of unsquared timber, laden with fascines and stones, were sunk between the exterior open piles, as well on the river, as on the sea-side, so as to cover the base of the embankment by a layer of about 4 feet in thickness. This arrangement was economical, and would have succeeded perfectly, had time been no object; but as the sinking of the fascines could only be accomplished during perfectly calm weather, the progress of the work became so slow, as to necessitate the employment of some other system, which would ensure greater rapidity of execution.

Recourse was then had to a plan which answered well in every respect, and by means of which the Author has been enabled to complete the works within the original estimate, and in less time than at first specified. The open pilework was advanced with all possible expedition, and the proposed seat of the advancing pier was paved with stones, delivered from barges. This pavement withstood the attacks of the sea, and offered no great obstruction to the penetration of the sheet piles, which, without being shod, were frequently driven 10 feet into the ground, after having been forced through 8 feet of rubble stones. In throwing down the stones from the barges, care was taken to pitch them close to, and equally on both sides of the sheet piling, until the stonework showed itself above the water line; and then, after the wedge-shaped upper portion had been distributed over a wider base by the action of the waves, to repeat the same process, until the slopes found their angle of repose. In this way no more stone was employed than was absolutely necessary for the stability of the work, which, when completed, might be described as a mass of closely packed third class rubble, resting on a broad base, and narrowing upwards to a level slightly below the surface of the water, at which point it became a mere ridge resting against the close piling; the side slopes of its section varying from 2 to 1 near the pier heads, to 1 to 1, and 1½ to 1, near the shore.

The piers were completed on the 31st July, 1861, and the time employed in their actual construction was thirty-one months, exclusive of three winter months each year, during which the Danube was frozen over, and all work was suspended, but inclusive of two hundred and seven days, during which it was impossible to work, on account of stormy weather. The length of the north pier is 4,631 feet, that of the south pier is 3,000 feet, and the depth of water in which they are built, varies from 6 feet to 20 feet. In their construction 200,000 tons of stone, and 12,500 piles, have been employed; and the cost per lineal foot has not exceeded ten guineas. The stone used was a hard blue limestone, and was transported 58 miles by water, after having been for the most part carted 2 miles to the river bank at Toulcha. None of the stones were heavier than two men could lift, or less in size than a common brick, and their highest price delivered at the piers, including all charges, was 5*s*. per ton, and the lowest price was 4*s*. per ton. All the longitudinal and transverse timbers, as well as the planking and fender piles, were of oak, and their cost was at the rate of 2*s*. 3*d*. per cubic foot; while the fir piles were delivered ready for driving for 4*d*. per cubic foot. The workmen, of whom there were generally three hundred, were composed of men belonging to upwards of ten different nations. Labourers were paid 2*s*. 6*d*. per day, and carpenters 4*s*. 6*d*. per day. The foreman of the works, Mr. Simpson, an Englishman, displayed an energy and ability in the execution of his duties, which were alike creditable to himself and to his country.

The earliest authentic document extant which shows the state of the Sulina mouth is the Russian government survey of 1829 (Plate 6). By comparing this with Mr. Hansford's survey of July, 1857 (Plate 7), the following changes to the north, and to the south, of the mouth will be noticed. On laying off an imaginary line, directly to the east of the Old Lighthouse, and using it as a datum line for the purpose of measurement, it appears that whilst the coast line remained stationary, the 15 feet line of soundings advanced 1,000 feet, and the 30 feet line, advanced 2,900 feet. In like manner, by drawing a line of 2,500 feet in length, directly to the north of the Lighthouse, and then striking off an imaginary perpendicular for a datum line, it appears that while the coast line receded 600 feet, the 15 feet line of soundings advanced 700 feet, and the 30 feet line advanced 3,400 feet.[1]

The depth on the bar since the year 1829 has varied between the extremes of 7 feet, and 12 feet; the least depth being found during the subsidence of high-water floods, and the greatest when the deposits lodged by these floods had been dispersed by the autumnal and winter gales. In July, 1857, when the works were commenced, the river margin of that portion of the Sulina bar where soundings gave less than 15 feet, was 2,000 feet distant from the north promontory of the mouth, and 4,000 feet from its sea margin. Near the centre of this long shoal, the navigable channel was only 9 feet deep. In November, 1859, when the works had been brought to a close for the winter, the north pier had advanced 3,000 feet and the south pier 500 feet. The depth on the bar was then 10 feet. From this period till the following April, although the works remained stationary, the depth of the channel increased to 14 feet. As this could only be attributed to the north pier, hopes were entertained that its action would be sufficient to maintain the improvement which, unaided, it had effected. These expectations, however, were soon disappointed, for during the spring and summer months, the unusually high river floods caused such a deposit at the mouth, that in August, when the north pier had reached a length of 4,600 feet, or to within 30 feet of its present extremity, the depth on the bar had diminished to 9¼ feet. The inadequacy, therefore, of a single pier to maintain an improved depth was fully demonstrated. Every exertion was then made to bring the opposite pier into play. Accordingly, during the next three months, the south pier was pushed out 1,500 feet further, and as it was then brought to within a distance of 600 feet from the north pier, the good effect of concentrating the whole force of the river current directly on the bar became at once apparent. Thus, on the 30th November, there was a good navigable channel of 12 feet; on the 31st December of 13 feet; and on the 28th February, 1861, of 14 feet. Then came the breaking up of the ice in the river, and the furious descent of the extraordinary high floods, which caused so much damage at Galatz, and submerged the whole delta; but this time, the swollen waters, being confined between the two piers, and directed in a proper line, instead of causing a diminution of the depth, fairly swept away the remains of the bar on to the south bank and into deep water.

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[1] By comparing the survey of July, 1857, with a survey, made by Mr. Hansford in July, 1862, about a year after the works were completed, and using the same datum lines as above, it was found that, on the south side of the mouth, the 15 feet, and the 30 feet line of soundings had remained nearly stationary, and that to the north of the mouth, the coast line had receded 100 feet, and the 15 feet line of soundings had receded 400 feet: while the 30 feet line had remained nearly in its old position.

From that time to the present, the depth has never been less than 16½ feet, and frequently as much as 17½ feet, over a navigable width of 500 feet. This result has been accomplished by works the cost of which has not exceeded the sum that was paid in one year only for lightening vessels over the bar, when its depth did not exceed 10 feet. Nor is this the only subject for congratulation. The immense gain to the shipping interest, in other and still more important respects, is incalculable. For some years before the improvements, an average of two thousand vessels, of an aggregate capacity of 400,000 tons, visited the Danube, and of this number, more than three-fourths loaded either the whole, or part, of their cargoes from lighters in the Sulina roadstead, where, lying off a lee-shore, they were frequently exposed to the greatest danger. Shipwrecks were of common occurrence, and occasionally the number of disasters was appalling. As an instance, on one dark winter night, in December, 1855, during a terrific gale, twenty-four sailing ships, and sixty lighters, went ashore off the mouth, and upwards of three hundred persons perished. At present no such disaster is possible. Vessels may enter at any time, and with any wind. Sulina, in fact, is now one of the best harbours of refuge in the Black Sea.

This summary of facts leads to the hypothesis, that if the good effects that have been already produced, should now be as suddenly lost, the expenditure on the works just described, would not have been unprofitably applied. Fortunately, no such catastrophe is immediately impending; for the comparison of the plans of the mouth which were made by Mr. Hansford, the skilful surveyor of the Commission, before the commencement and after the termination of the works, (Plates 7 and 8,) shows that while deposits to a small extent have taken place in the interval to the south of the improved channel, there have been no deposits whatever to the north. This evidence is encouraging for the future, and sustains the position that has been so much insisted upon by the

Commission, that the system of parallel piers, as applied at the mouth of the Sulina branch, is the best, that under the circumstances, could have been devised for an improved sea entrance to the Danube, even with the certainty attached to it—which is not denied—that to maintain the improvement, and to keep pace with the formation of new sand banks, or the growth of old ones, the guiding works must eventually be prolonged.

The Author cannot conclude this Paper, without expressing his sense of gratitude to the members of the European Commission of the Danube, for the generous support he has received from them, during the five years he has had the honour to act as their engineer; and this acknowledgment is more especially due to the British Commissioner, Major Stokes, of the Royal Engineers, whose prompt and energetic action, at moments of difficulty, mainly contributed to the due accomplishment of the works herein described; and he further hopes that the labours of the Commission will eventually secure to the commerce of all nations, the best possible means of water communication with the rich corn-growing countries bordering the shores of the Lower Danube.

The Paper is illustrated by a series of diagrams, from which Plates 5, 6, 7, 8 and 9 have been compiled.

[Mr. HARTLEY,

PLATE 5. VOL.XXI.

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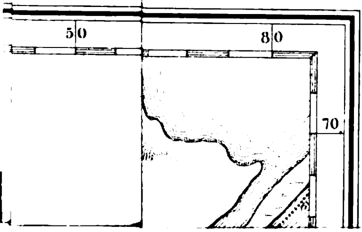

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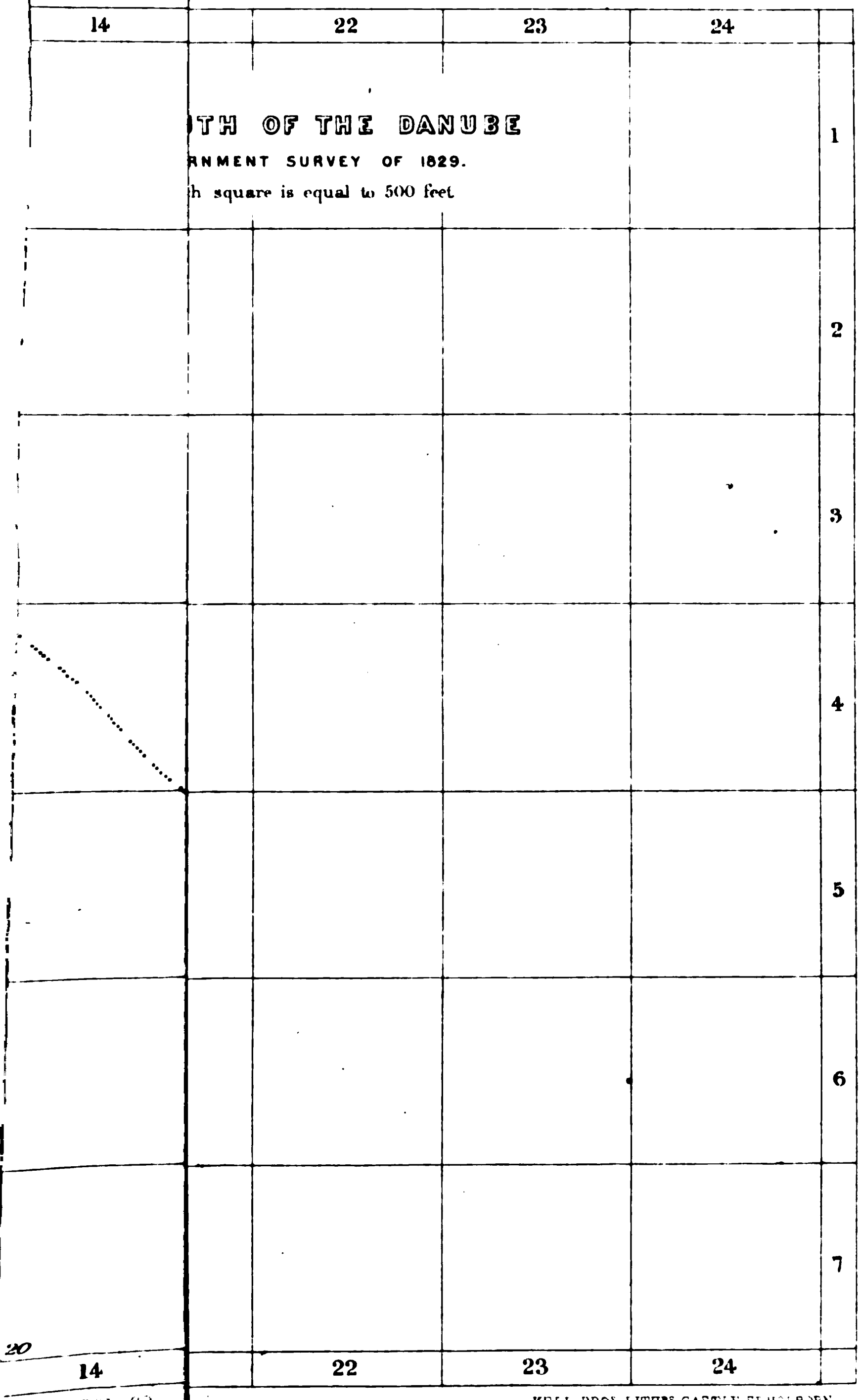

TH OF THE DANUBE

RNMENT SURVEY OF 1829.

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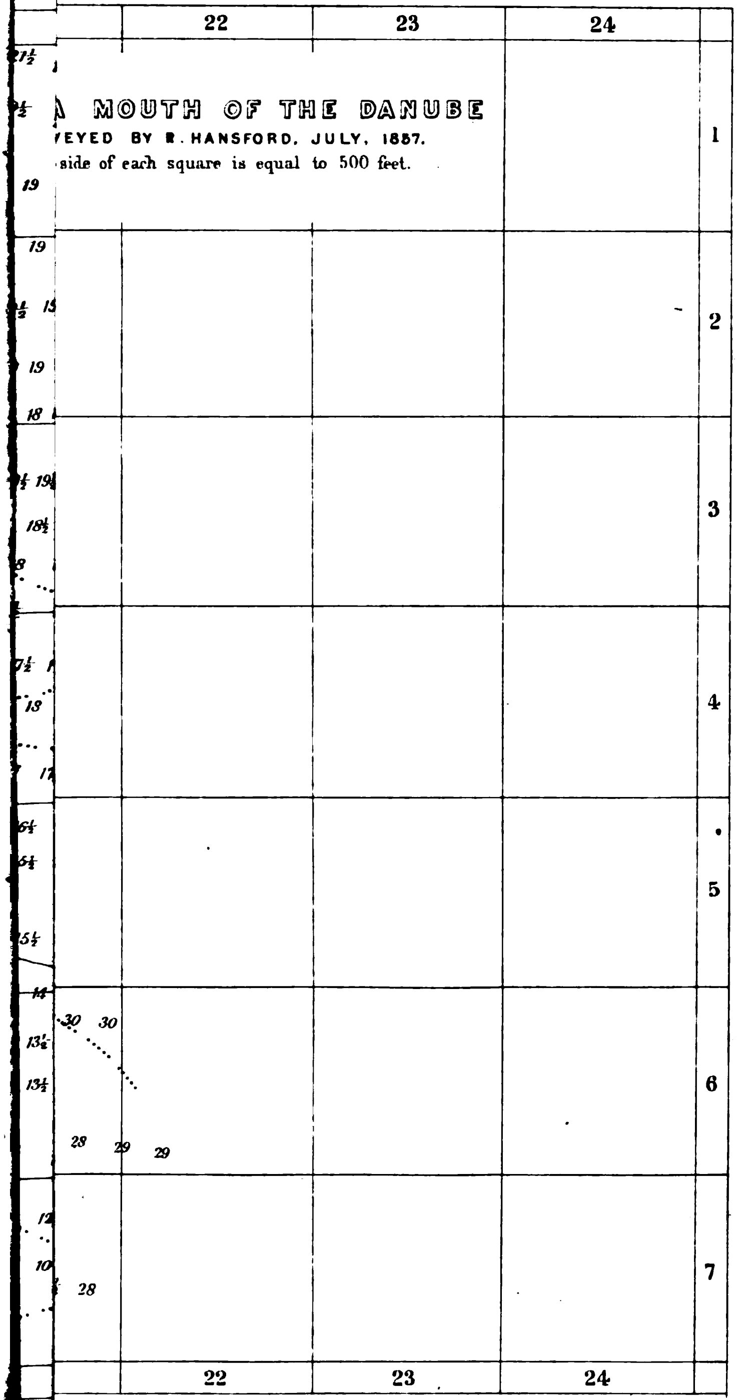
PLATE 7. VOL:XXI.


A MOUTH OF THE DANUBE
VEYED BY R. HANSFORD, JULY, 1887.
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KELL BROS LITHRS CASTLE ST HOLBORN.

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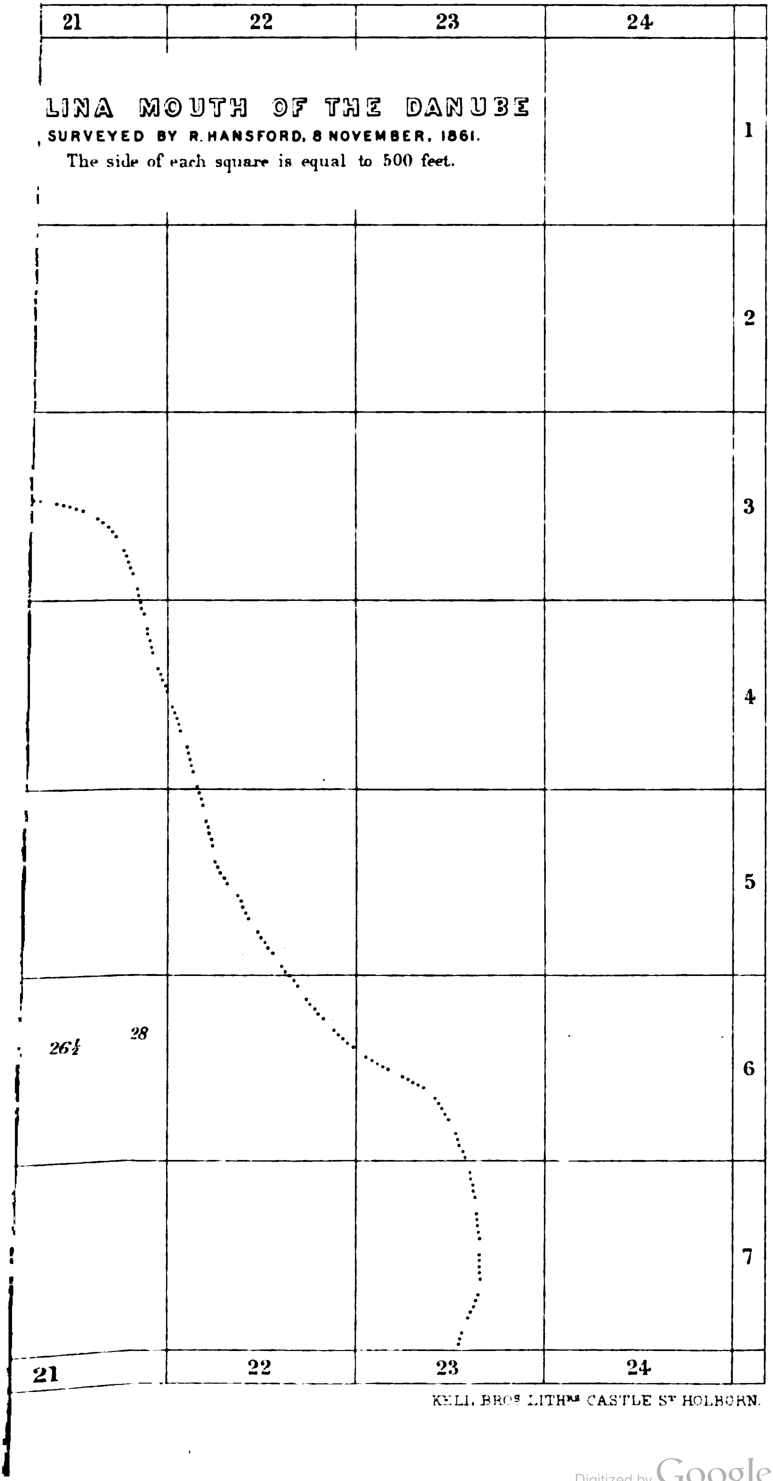
PLATE 8. VOL.XXI.



LINA MOUTH OF THE DANUBE

SURVEYED BY R. HANSFORD, 8 NOVEMBER, 1861.

The side of each square is equal to 500 feet.

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KELL BROS LITHRS CASTLE ST HOLBORN.

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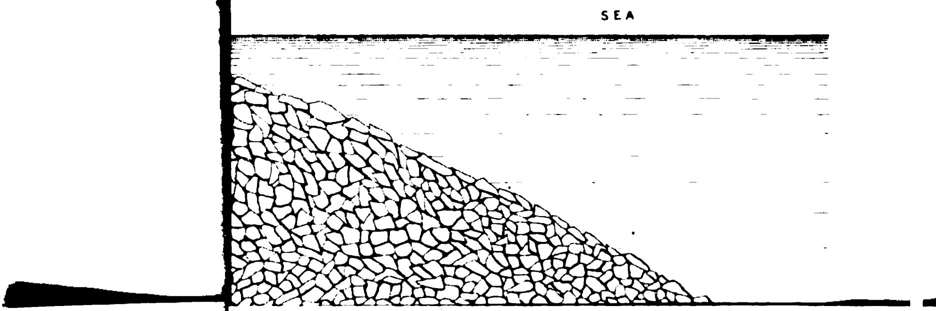
THE DANUBE

PTH OF 18 FEET OF WATER.



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Mr. HARTLEY, in reply to questions, stated, that the average depth of the piers was about 14 feet. They were constructed of a hard kind of limestone, somewhat similar to that used at the Plymouth breakwater. The timber piles, 13 inches square each, were driven in some instances through a bed of rubble which had been previously thrown down. This rubble varied in dimensions from the size of a brick, to boulders of as great weight as could be lifted by two men. The sheet piles were 10 inches by 12 inches.

Mr. T. E. HARRISON stated, that about three years ago, Major Stokes, the British Commissioner, laid before him the whole of the papers bearing on this subject. The question for decision then was, whether the Sulina, or the St. George Channel, should be adopted. An important fact bearing on that issue was not mentioned in the Paper; namely, that, setting across from the Crimean shore, there was a constant current of about a knot an hour, which invariably maintained a southerly direction. The existence of this current would account for the position of the accumulation which had taken place since the erection of the new works. The whole of the deposit brought down by the different mouths of the Danube constantly tended towards the south. It would be seen that the deep-water line coming across from the opposite coast, impinged upon the point at which the St. George branch discharged itself, while it passed a considerable distance to seaward of the Sulina mouth. He therefore considered, that if the St. George mouth had been selected, the southerly current passing the end of the piers would probably have maintained a greater depth of channel, than at the comparatively embayed mouth of the Sulina. The Commissioners were of opinion, that the general navigation of the St. George was better than that of the Sulina: so that, having regard to the ultimate improvement of the navigation of the Danube, the conclusion he came to was, that if it were intended to make the river permanently navigable, attention should be devoted to the St. George mouth, in preference to that of the Sulina.

One plan suggested was, that instead of carrying out the piers at the mouth, a communication between the river and the sea should be formed by an independent canal, to be furnished with gates to prevent the entrance of the river waters, but he could not advise its adoption. That plan—although it had been recommended by the Commissioners who met at Paris—was not approved by Major Stokes. After a full consideration of the case, Mr. Harrison arrived at the conclusion, that if anything was to be done with the Sulina mouth, the principle of the plan which had been so successfully designed and carried out by Mr. Hartley was that which should be persevered in. But if further works were undertaken for the improvement of the navigation of the Danube, he believed that any expenditure upon the St. George mouth would ultimately be amply repaid.

Mr. J. R. M'Clean, V.P., had an opportunity of examining the works at the entrance of the Sulina, and could bear testimony to the excellent manner in which they had been executed. The general opinion in Moldavia was, that they had been extremely successful; and all classes agreed that the beneficial results were principally owing to the constant devotion, and to the talent and ability displayed by Mr. Hartley, during their construction. It was extremely gratifying to find, that an English Engineer had carried the reputation of his profession so far into the east of Europe, and that his labours were so highly appreciated in the locality; more especially as he had to compete with the Engineers of Europe in the original design of the work.

Mr. John Murray observed, it was stated in the Paper, that the Kilia branch, previously to its subdivision, received seventeen twenty-sevenths of the whole water passing down the river; while the St. George channel took eight twenty-sevenths, and the Sulina the remaining two twenty-sevenths. But it appeared that the St. George divided itself into two, or three branches, as it approached the sea, and hence he would ask Mr. Hartley whether there was any impracticability in closing one, or more of these branches, as, if that could be accomplished, a larger body of water would run down the main channel, producing a stronger current, and in consequence, a greater depth, towards the sea. If the quantity of water was doubled, the scouring effect would be fourfold; and as the St. George was 1,200 feet wide, with a minimum depth of 16 feet, and had 5 feet to 8 feet over the bar in its natural state, the increased body of water which would result from closing up one, or more of these branches, would produce great effects. The Sulina had no branches from which the quantity of water could be increased. It was only 300 feet wide, and the upper part of its navigation was intricate, owing to the sandbanks by which it was encumbered. The St. George branch did not appear to have sandbanks in it, although its channel was more winding: some of the bends might be cut off, and there was only a distance of 64 miles from the sea to the fork below Toulcha. A cut of only 1,700 feet was required to shorten the navigation by 3 miles, consequently the length could be reduced to 61 miles; and if two, or three, other cuts were executed, the total length of the channel could probably be made equal to that of the Sulina. The St. George having a larger body of water, conjoined with a wider and deeper river, was to be preferred. It also had the advantage of being situated to the south of the delta, and further of being subjected to the littoral current. Whereas the Sulina, being situated nearly in the middle of the delta, had its embouchure open to deposit. The depth of water 3 miles from the shore, at the St. George mouth, was 16 fathoms, while at the Sulina it was only 10 fathoms, and at the Kilia it was even shallower. The St. George channel was, also, the most accessible, and it had a sheltered bay to the south. Therefore any future works of a permanent character should be executed at the St. George channel, in preference to the Sulina.

Looking at the lower reach of the Sulina, running as it did almost due east, he could understand why the pier on the north side of the entrance had been commenced from the most prominent part of that shore. This point of departure, however, entailed the incidental formation of an internal recess, or foreshore, which required one, or more groynes to be carried across it to produce a proper action in the descending current. In the extension of the pier, its direction had been altered to a north-easterly course convex with the current. The reasons for this change were not noticed in the Paper, but it was to be presumed there was some good cause for the alteration. If it had been carried out a point or two more to the southward, in a curved direction, so as to allow the water to pass along its concave face, the action of the current would have been more direct on the bar. He also considered that the south pier should have been commenced at the extreme point of the shore, and thence carried out to the north-eastward in a straight direction, until sufficient width had been left for the waters of the river; from which point it should have been continued also in a straight direction nearly parallel with the north pier, which should have been allowed to overlap it as at present. By so doing a bight would have been left at the landward end of the south pier, which would have been found useful, in quelling and dispersing any waves which might enter the river between the piers. A considerable length of the south pier might also have been saved, and better effects would have been produced by the concentration of the descending current, which would have joined that of the littoral in its southerly course; in place of contending against it, as it now did, by the direction which had been given to the extremities of both piers.

Mr. VIGNOLES said, that a remarkable case was presented to the consideration of Engineers in the attempts to deepen the Bar of the River Adour below Bayonne, where the piers had been carried out for a distance of about a mile and a half in nearly parallel lines, and with a narrow channel. In the Bay of Dublin there was an entire contrast to the preceding system. The pier on the right bank of the channel was carried out nearly straight whilst the other pier came from the opposite shore nearly at right angles. The works in Dublin Bay had been a perfect success, whilst those below Bayonne had been an entire failure. These were two great examples which every Engineer should consider. It was very true, as appeared from the reports of the Admiralty, that the depth of water at the Sulina entrance to the Danube had been increased several feet, but it might be doubted whether this increased depth would be permanently maintained throughout the channel. At Bayonne the depth was said to have been increased, but inside the piers, at a distance of half a mile from the original bar, an interior bar had been formed—from what cause he was not prepared to say—but it was of such extent as to decrease the available channel to one-half its original width. He admitted that up to the present time, the Sulina bar had been considerably reduced; but looking at the preceding examples, he doubted whether the principle of the parallelism of the piers, was one from which a permanent benefit would be produced.

Mr. HEMANS could fully confirm the statement with regard to the effects which had been produced by the works in Dublin Bay. In that instance the piers had not been laid down parallel to each other, as at the entrance of the Sulina. In fact, the two sides of the enclosed portion formed a triangle with a very large base, through which the River Liffey took its course. A simple cause rendered this a better form for the direction of the piers in a tide way than parallel lines. There was a considerable amount of tidal water brought by the flood into this large triangle, which during the ebb, augmented the scour derived from the Liffey, and thus the action on the bar had been greatly increased. Mr. Hemans believed that the works at Dublin were larger in their extent than those described in the Paper, and that the piers were longer and of more solid construction.

Sir JOSEPH PAXTON did not consider that the cases of the comparatively inconsiderable rivers, Adour and Liffey, could be cited as bearing upon any question in relation to a river of such magnitude as the Danube. It was true that the application of converging piers to the broad tidal estuary of the Liffey had been successful; but the extension of the same principle to the tideless entrance of a capacious fresh-water channel, was at best but a matter of speculative theory. The data which had been laid so ably before the Institution had clearly shown, that the works at the entrance of the Sulina had proved a practical success. The able and efficient manner in which Mr. Hartley had designed and carried out the works at the Sulina mouth of the Danube, and the careful manner in which the Paper before the Institution had been prepared, were such as to entitle that gentleman to the highest meed of approbation.

Mr. W. A. BROOKS observed, that the improvement of Dublin Harbour was not a case in point, because in that example the action was mainly due to tidal water enclosed by the piers. A parallel case, however, existed in the Baltic, a tideless sea, in the works for the improvement of the Harbour of Swinemunde, where only a single pier to the east of the entrance had been run out. It had been constructed with its concave face exposed to the action of the debouching waters, and was subjected, also, to the scouring action of the littoral current, which set from west to east, or directly on the concave face of the pier. There was no second pier at Swinemunde, but mooring, or warping piles were placed at intervals along the west, or convex shore. The result was, that a permanent deep-water channel, having a depth of 18 feet, was established alongside the pier, and all detritus was swept past the pier head to the eastward. The same principle ought to have been applied at the mouths of the Danube. He thought the system of forming piers concave to the current of the ebbing water, and also presenting their concave side to the direction of the littoral current, was preferable to the principle adopted in the works at the mouth of the Sulina. It would have been better to have formed the pier from the south side of the mouth of the river so as to compel the effluent water to range along it.

Mr. A. GILES noticed, that owing to the formation of the delta, the deposit from the Kilia would travel to the southward, and a bar would again be formed at the Sulina. To render permanent the works already executed, an extension of the piers in a southerly direction would therefore be necessary.

Mr. RENNIE had been professionally connected with the Danube since the year 1837, when he was consulted about the Danube and Mayne Canal, as well as relative to improving the navigation of the Danube itself, and again in 1839, in reference to the building of a bridge over that river between Buda and Pesth. His visit enabled him not only to inspect the maps and surveys of the river which had been made by order of the Government, but also to verify, by a number of experiments, the mean velocity and regime of its waters in many parts of its channel. He had further the advantage of the counsel and advice of the late Count Széchenyi, who at that period was the sole Commissioner of the Danube, and the originator of most of its subsequent improvements, including amongst them the introduction of steam navigation. In 1847—agreeably to a convention which had been made by the English, Austrian, and Russian Governments in 1840—Messrs. Rennie sent out a dredging machine to the Sulina mouth, for the purpose of being used by the latter Government, in deepening the water over the bar. The dredging machine was set to work in April, 1851, and it effected a considerable lowering of the bar. In favourable weather ten barges a day were filled and discharged. But such were the defects of management, that after working at long intervals, the dredging machine was entirely withdrawn, and the depth of water over the bar, which had been formerly maintained by the Turks at from 16 feet to 17 feet, was allowed to decrease to 8 feet, or 10 feet. In 1855, he brought forward a project for the improvement of the Sulina mouth of the Danube, which in some respects differed from that which had since been so successfully executed. In the existing works the widest, or bell-mouthed part had been commenced at the seashore; whereas he had proposed that the reverse principle should be adopted: namely, that the piers should be only 450 feet apart at their junction with the shore, and 600 feet apart at their termination.

Admiral Sir EDWARD BELCHER observed, that by an established law of nature, deep water prevailed wherever a curvature was exposed to the action of the ebb tide. He thought that if the northern pier at the Sulina had been inclined, so as to receive obliquely the direct line of the river current, and thus cause it to sweep on that curve to seaward, it would have deepened the course along that line of pier, and the current would have impinged with a stronger scouring force on the outer bar. After an experience of fifty years he considered it might be safely assumed, that wherever it was desired to deepen a river by means of artificial walls, the stream should be judiciously trained from reach to reach, so as to act obliquely along the curvatures—thus assisting nature in performing the work easily and surely.

Mr. F. W. SHEILDS said, that in forming an opinion, the peculiar conditions involved must be carefully considered. There was not any analogous case in this country of a river, having a copious flow of water, carrying down a large quantity of deposit, entering into a tideless sea. There were two mouths of the Danube, the Sulina and the St. George, both of which could, without much difficulty, be made available for navigation. One discharged only about one-fourth the quantity of water of the other; and the water carried with it into a tideless sea a large quantity of deposit. This deposit was, however, partially removed, by a littoral current passing from north to south. Now, as the quantity of deposit at each mouth, was in proportion to the quantity of river water, it was a circumstance in favour of the Sulina mouth, that the deposit formed there, was only one-fourth of that at the St. George; and therefore the littoral current (the force and velocity of which might be presumed to be equal at both mouths), had a much better chance of removing the smaller quantity of deposit of the Sulina, than the larger quantity which passed from the St. George. For that reason, and looking at the results already obtained, he thought the probability of a comparatively permanent improvement much greater than had been anticipated. With regard to the blocking up of one branch altogether, and throwing the water of the united streams into one channel. No doubt that might have been done, at the time of low water, at a less cost than constructing 7,000 or 8,000 feet of sea walls; but the result would have been a still greater increase in the quantity of deposit, and the liability to form a bar would have been greater than at present. He had no doubt, therefore, that the expenditure on these works had been incurred on a safe basis, and that their results would be comparatively permanent.

Mr. G. P. Bidder,—Past President,—observed that, without personally inspecting the locality, it would be presumptuous to pronounce which mouth of the river was the best to be rendered navigable. It appeared to him that the works had been carried out in a very practical manner. The Paper seemed to confirm a theory which he had long held, as to the relatively small mechanical effect of land water as compared with tidal water, and the facts stated bore prominently on that important subject. He would contrast, so far as the Paper enabled him to do so, the conditions of the Danube with those of the river Thames. The Danube was stated to be a river draining 300,000 square miles of land. It passed through a channel 1,700 feet wide, having a depth of 50 feet; the minimum velocity of the current being 1 knot per hour, and the maximum velocity, 5 knots per hour. The quantity of water discharged, varied from 7½ millions cubic feet per minute, to 60 millions cubic feet per minute, and at moderate floods amounted to 19 millions. All this vast amount of water was poured into the tideless Black Sea. Now all the land water flowing down the Thames during a whole day did not amount to so much as passed down the Danube in a quarter of an hour. Yet the state of the navigable channel of the Thames was very different from that of the Danube. At Gravesend, where the river was more than three quarters of a mile wide, it was 50 feet, or 60 feet deep, and that depth was permanently maintained. Then proceeding to the mouth of the Thames, where there were three or four channels, all more or less navigable, so as to enable the Great Eastern to find her way along the estuary to the sea. Could it be said that these depths were maintained by the mere driblet of land waters which passed over Teddington Lock, as compared with the mighty flow of the Danube? Was it not rather due to the rise and fall of tide in the Thames of from 18 feet to 19 feet at springs and from 14 feet to 15 feet at neaps? If it were possible to keep back all the land water of the Danube, and a rise and fall of tide of 5 feet, or 6 feet, could be given in exchange, he believed, that a deeper channel would be maintained, than with the existing enormous force of land water, and all the aid which the skill of man could devise. He considered that the theory of the regime of rivers and the effect of tidal scour, as compared with that of land water, remained yet to be developed and discussed.

Mr. HARTLEY, in reply, said that he quite agreed that the St. George branch possessed decided advantages over that of the Sulina, and he had always expressed that opinion to the European Commission of the Danube. He wished it to be clearly understood, that he only designed the works at the Sulina as those which were most applicable when that branch was chosen from motives of expediency, or economy, in preference to the St. George. He had never lost sight of the littoral current, as a valuable auxiliary power for maintaining an improved channel at the entrance. That current flowed directly towards the Bosphorus during calm weather and northerly winds. Its flow to the south, sometimes exceeded a knot an hour, and its influence was decidedly greater at the St. George than at the other mouths, on account of the salient angle which the St. George promontory presented to the wearing influence of the sea currents in whichever direction they might happen to flow. It should, however, be borne in mind that, although with northerly winds and during calm weather, the current of the sea was directed to the south, the reverse was the case during southerly winds. The greater sea depth opposite to the St. George, as compared with that opposite the mouths of the Sulina and Kilia, had been referred to in the Paper; and when he stated in addition, that adjacent to the N.E. shore of the delta the sea bottom had only an inclination of 1 in 400, while the slope opposite the St. George was less than 1 in 200, he need not say another word to prove, that the St. George bar once reached by parallel piers, the prolongations necessary to keep pace with new deposits, would be less considerable than at the other mouths. He could corroborate the assertion, that although Major Stokes, the British Commissioner for the Danube, was decidedly opposed to opening the St. George by means of a canal independent of the mouth, he had always strenuously advocated the improvement of the mouth itself by means of parallel piers. Major Stokes had invariably expressed himself in favour of the St. George, and had never lost an opportunity of bringing under the notice of those whom it most concerned, the many striking advantages it possessed over the other branches.

Mr. Hartley would have preferred to have carried the piers due east, so as to have continued the direction of the last reach of the river, and also to have commenced the south pier at the extreme east point of the south shore. He quite agreed that the St. George mouth ought to have been selected for permanent improvement, on account of its superiority over the other mouths in a nautical point of view.

He likewise believed, that if the mode of treatment which had been employed at the Sulina mouth, had been applied at the St. George, although the cost would have been greater, the results would have been more satisfactory, and certainly more durable. He did not consider it would be desirable to close the minor channels of the St. George, in case of its attempted improvement. Two-thirds of the volume of the St. George passed to the sea by the Kedrilles branch, and this would insure at all seasons a sufficient navigable depth over a new channel of from 800 feet to 1,000 feet wide. It must be remembered that the amount of deposit at the mouth was almost directly proportional to the volume of water delivered by that mouth to the sea. Hence, after having provided for a sufficient width and depth of channel, it had been considered undesirable to add more water than was absolutely necessary for the conservation of its normal dimensions. For this reason he did not propose to close the Olinka Channel, which was the outfall for the remaining third of the St. George—the loss of water by the Donavitza branch being utterly insignificant,—until experience should have shown that such a course was advisable. With reference to the artificial cuts, he might state briefly that by cutting through three bends of the St. George, its course could be shortened nearly 17 miles; and although eventually, when a large revenue would warrant such an outlay, those improvements might be effected, they were not now considered indispensable. All naval men who had studied the question, were of opinion, that owing to the great width and depth of the St. George, its numerous windings offered no real obstacles to the navigation.

Referring to the direction and length of the Sulina piers, he reiterated, as had already been mentioned in the Paper, that their general direction had been designed to be E. by N., with the object of sheltering the port, and of allowing vessels to enter during every on-shore wind; also that the south pier was designed to be considerably shorter than the north pier, for the following reasons:—"first, it was considered unnecessary, and indeed undesirable, owing to the configuration of the coast, that the piers should run parallel to each other until the bar was reached; and advantage was therefore taken of the projection of the south lip, beyond the opposite shore, to commence the south pier, from a point nearly 1,000 feet seaward of the commencement of the north pier; secondly, in order to shelter vessels entering and leaving the harbour, during the prevailing N. and N.E. winds, the north pier was designed to overlap the south pier 600 feet, a length equal to the normal width of the river, and also to the space between the piers where their parallelism commenced."[1]

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[1] *Vide* ante, p. 286.

In addition to this he might mention, that in fixing the general direction of the piers, he was also influenced in his decision by observing the usual course of the deepest channel across the bar before the improvements were commenced. He found that the deepest water was always to the north of east, and that this was the case also at the mouths of the Kilia. Nature having thus pointed out the best direction, he determined to follow so good a guide, and accordingly the ends of the piers were so arranged as to direct the waters one point to the north of east; in fact, in the direction where formerly, before the mouth was altered, the deepest navigable channel was generally to be found. This direction, moreover, was perpendicular to that of the coast, which here ran N. by W., and, consequently, was the best that could be given to facilitate the manœuvring of shipping at the entrance.

With regard to the starting point of the south pier, he considered that if both piers had been commenced from the same meridian line, and had thence run parallel to each other at 600 feet apart, the cost of the works would have been greatly increased, and during easterly winds there would have been more movement inside the port, for the waves would have been guided inwards along the concave face of the south wall; whereas by the arrangement adopted, they spent themselves harmlessly on the south beach. On the other hand, with a parallelism throughout, the depth of the channel would not have been subject to the same variations as at present, and this uncertainty might fairly be set against the advantages above alluded to. The risk, however, was worth running, and it was not dangerous, for in case the channel opposite the commencement of the south pier should shoal, on account of its disproportionate width, it would not be difficult, or costly, to continue by light river works, the parallelism of the piers from the entrance inwards. In fixing the starting point of the south pier, he took advantage, as far as was prudent, of the projection of the south shore beyond that of the north shore, the object in so doing being to insure the removal of the sandbank forming the bar solely by the force acquired by the river current being confined within narrow limits; and to accomplish this object, the piers were brought comparatively near together at the western skirt of the bank. In this respect his anticipations had been fully realised. If the south pier had been commenced at the extreme point of the south shore, the parallelism of the piers would not have commenced so soon, and, consequently, there would not have been the same probability of providing an uniformly deep and permanent channel from the port to the sea. From whichever point the south pier might have been commenced, and in whichever way directed, he was of opinion that there would always be nearly the same amount of backing-up behind, or to seaward of it. The advance of the south bank would be inevitable, and after a time that difficulty could only be met by a further prolongation of both piers.

Although the piers might not be quite permanent, or were not likely to insure a permanent improvement, it should be remembered that they had been constructed at a remarkably small cost, considering the end they had to serve, and the country in which they were built, and that they had achieved a greater improvement in less time than even the most sanguine had ventured to predict. The mode of their construction was such, that they could readily be made what was called permanent, at a comparatively small cost, by widening the base of the 'pierre perdue,' and by substituting a superstructure of masonry, for the existing perishable upper framing of timber; but even then, if their full value was to be perpetuated, they must be prolonged seaward, as occasion might require. It was to be hoped, however, that instead of thus rendering the Sulina works permanent, means would soon be found to enable the Danube Commission to complete works of a definitive character at the St. George entrance, which, as he had already endeavoured to show, possessed many advantages over that of the Sulina. One of the most prominent of these was the existence of a good navigable river channel at all seasons, from Kedrilles at the mouth, to the towns of Galatz and Ibraila, instead of a channel encumbered, like that of the Sulina, with numerous shoals, the attempted removal of which would be attended with great expense, uncertainty, and loss of time.

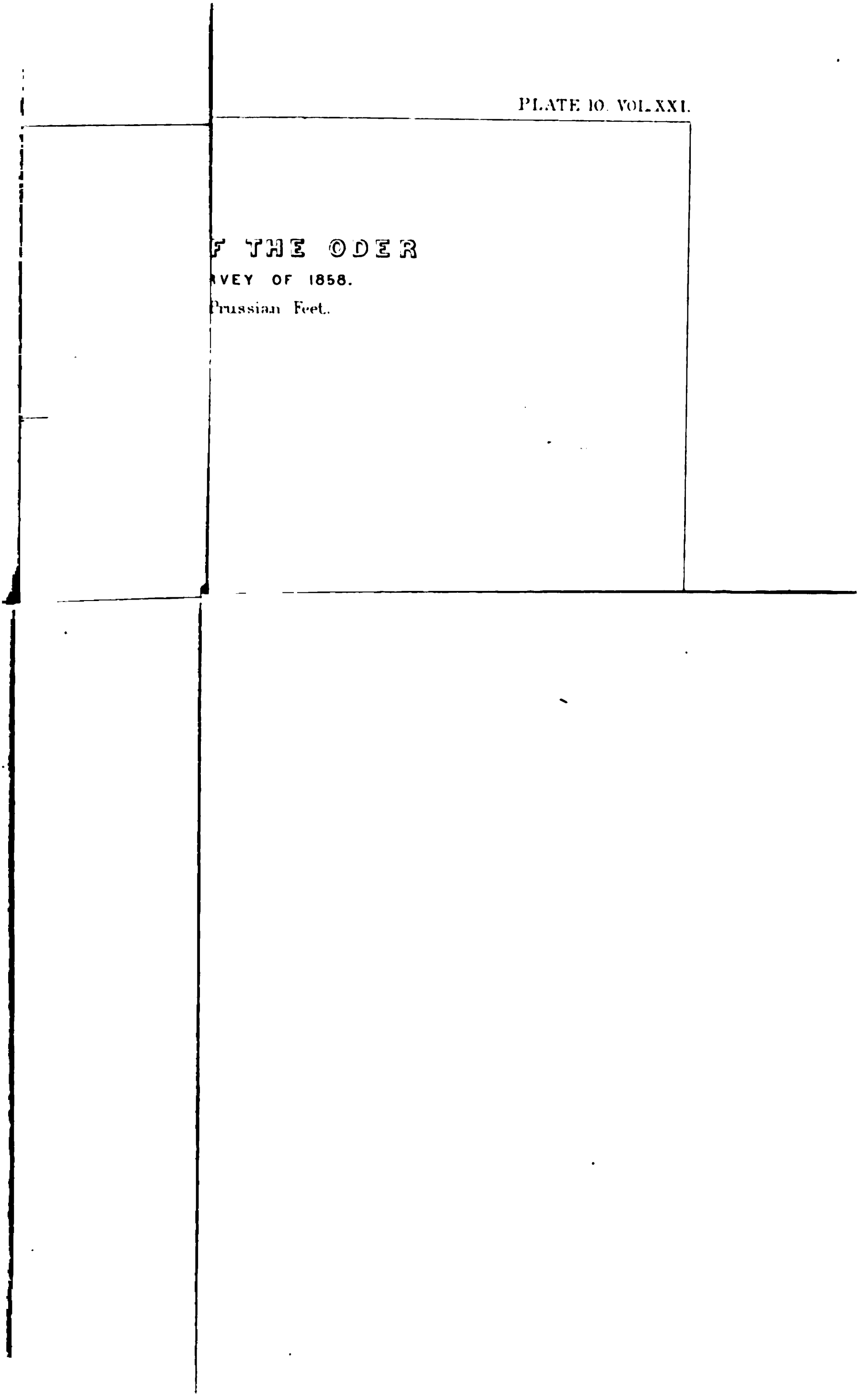
Although he by no means looked upon the improvement which has been effected at the Sulina mouth, as likely to be permanent, he could not regard the want of success at the mouth of the Adour as a case in point. The Adour was a tidal river. Its bar was obstructed by shingle, and the mode of treatment which had been adopted, had been that of directing the current seawards by 'digues à claire voie,' or open framework. This method had not been adopted at the Sulina, where there was neither shingle, nor tide; indeed, there was but little analogy between the two cases.

It had been stated that it would have been preferable if the space between the piers had been more funnel-shaped, so as to allow of a better scour at the entrance; and in illustration the case of Dublin Harbour had been quoted, where such an arrangement of piers had been remarkably successful. With reference to that mode of treatment, he considered that, the more the funnel form of piers was carried out at the entrance of a river entering a tideless sea, the greater would be the risk of throwing up new shoals, at the places where the water spread over a wider section, than it occupied under normal circumstances, in those reaches of the river where the depth and width continued constant and sufficient. The arrangement at Dublin was undoubtedly good, because that was a tidal harbour; but at the Sulina mouth there was no tide, and consequently no need of a store basin within the piers to increase the scour at the entrance. The extreme ends of piers designed to improve the outfall of such a river as the Danube, which emptied itself into a tideless sea, should be preserved parallel at a distance apart equal to the natural width of the channel for a certain length within the mouth. This was necessary to insure the removal of the sandbank which formed the bar, and also that the piers might offer the best direction for the continued prolongations which would ultimately be necessary to maintain an improved depth. On this account, especially, he was opposed to what were sometimes called bell-mouthed, and funnel, piers. It was true that he had adopted the latter form to a certain extent at Sulina; but then it would be seen the piers were parallel to each other for a few hundred feet at the ends, which provided in the best manner possible for future extensions, should they ever be considered necessary.

The case of the Swinemunde improvements had been cited in support of an opinion, that the construction of a single pier run out in a curved form eastward, in prolongation of the right, or south bank of either the St. George, or the Sulina mouth, would be sufficient in itself to form a deep-sea entrance to the Danube; and it had been said, that the action of the east pier alone at the Swinemunde mouth had been instrumental in maintaining a greatly improved depth over the bar channel. Mr. Hartley knew from personal observation that there was a west as well as an east pier at Swinemunde, and that each of these piers had a width of 60 feet at the water-line. He could not agree that the construction of one pier only, either at the St. George, or at the Sulina would be sufficient in itself, even if properly curved and directed, to deepen and maintain an improved sea entrance. Evidence had already been given in the Paper, that the north pier was insufficient, in itself, to maintain an increased depth, and he believed, that if the same experiment had been tried with a south pier, laid out on the line proposed, the same barren result would have followed. He was quite prepared to admit as a general rule, that in all curved water-courses bounded by indestructible parallel works, the deepest channel was to be found along the concave side of such banks. Hence in his project for the St. George mouth he anticipated that the greatest depth of channel would be found along the inside of the south pier. These anticipations, however, would have been by no means strong, if the waters had been directed by the south pier only; for where would have been the guarantee in such a case, that a bar channel of insignificant depth, would not have formed itself occasionally as heretofore, in an E. by N., E.N.E., N.E. by E., or N.E. direction? and, that the strength of the current, instead of being concentrated directly upon a space limited to a width of less than 1,000 feet, would not, on leaving the river, have been spread uselessly over the N.E. quadrant of a circle, with a supposed centre situated at the most advanced E. point of the left river bank facing the sea? The absence of a north pier, moreover, would unfit either the St. George, or the Sulina for being, what the latter really now was, a good harbour of refuge; for without protection from the north, and a pier on the south, no vessel would attempt to enter during the prevailing N.N.E. winds, which were those that blew the strongest and longest as well as raised the most dangerous seas. So well was this known to mariners frequenting the Danube, that it was a common saying among them, that if the north pier at Sulina had done nothing else but shelter the harbour, and if it had not even been the means of gaining an extra inch of depth, the money it cost would have been well expended. It had also been said that the direction of Captain Spratt's proposed south pier for the St. George had been judiciously chosen. Without attempting to contest that statement, Mr. Hartley would merely remark, that Captain Spratt had always been of opinion, that the construction of two piers, converging towards each other, and directed east, were necessary to insure an improved sea entrance to the St. George; and that, in point of fact, that officer regarded the construction of a north pier as indispensable.

Recurring to the improvements which were carried out upwards of thirty years ago at Swinemunde, he would refer to the Prussian Survey of 1858 (Plate 10), and to a few notes he had made on that subject, when he visited those works three years ago. On that occasion he was accompanied by Mr. Exner, an Engineer-in-Chief attached to the Prussian government. In the year 1818, when the works were commenced, the depth on the bar at Swinemunde did not exceed 7 feet. Ten years afterwards, when they were completed, the depth had been increased to 28 feet, and at the time of his inspection there was a good navigable channel 18 feet deep. In deciding on the line of the east pier, it was determined to follow, as nearly as possible, the direction of the river current, which for fifty years previously had flowed in a N.W. direction, and to aid in maintaining the channel by a constant scour. The plan of the pier was on a curve, and the direction generally was such as to secure the interior of the harbour from the effects of heavy storms, which were most felt when they set in from the N.E. The west pier—which was very solidly constructed with fascines and stones—was erected with a view to arrest the progress of sand brought towards the harbour by the littoral current, and to fix the fluvial current in one direction. The east pier was 4,400 feet in length, and projected 1,400 feet beyond the west pier; which, although its root was now far in shore, originally had a length of 3,300 feet. The distance between the piers at the extremity of the west pier was 1,150 feet, a width which was more than double that of some of the reaches of the river near Stettin. The prevailing winds were from the N.W., and the littoral current was from west to east. The extreme difference between high and low water at the entrance was 5 feet. High water was produced at the entrance when the wind blew strongly from the N. and N.E. The sea then entered the large fresh-water lake called the Stettin See. Low water occurred when the wind veered round to the south. The surplus water stored in the Stettin See was then discharged, and during its passage seaward exerted a very beneficial effect in cleansing the channel between the piers. The waters of the Oder passing by Swinemunde, even during upland floods, contained a very small proportion of matter held in suspension. This arose from the lakes, through which the Oder made its way, acting as settling basins and receiving the deposits of the river before it reached the sea. In spite of these great natural advantages for maintaining a deep-sea entrance, the channel alongside the east pier, was only maintained at a navigable width of 450 feet, and freed from the deposit brought in by the prevailing winds and littoral currents by constant dredging. In order to render this expensive operation less necessary, it had been proposed that the direction of the east pier should be changed, and that a reverse or S curve should be given to it, so as to direct the river current to the N.N.E., and to prolong the west pier, bringing it nearer to the east pier, so as to shelter the entrance from the prevailing winds, and to improve the scour outwards. He therefore contended that the previous history of the works at Swinemunde could not be adduced to prove, that the projection of one curved pier was sufficient to deepen and maintain an effective sea entrance to one of the mouths of the Danube. On the contrary, it seemed to prove that a second pier was indispensable, and that the width between them should not exceed, as a general rule, the normal width of the river itself at those portions where the depth was sufficient for the purposes of navigation. Otherwise, either dredging must be had recourse to, or groynes, or longitudinal works must be constructed to insure an uniformly deep channel.

At the Sulina mouth he had no apprehension as to the maintenance of a sufficiently good channel between the piers, whether



F THE ODER
VEY OF 1858.
Prussian Feet.

OF THE UNIVERSITY OF CALIFORNIA

the radius of the curved wall was great, or small, although he should prefer the former, as the foundations of the concave pier would be less liable to be attacked, and the deepened channel between the piers would be less irregular in section. His only fear was that new banks would eventually be formed beyond the pier heads, and thus necessitate their further prolongation. He likewise thought that, considering the direction of the prevailing winds and of the littoral current, it was desirable that the piers should have the effect of directing the river waters seaward, as far as possible in the same direction, so as to keep the entrance clear of deposit. It must be remembered, however, that such a disposition of the piers at the Sulina entrance would cause them to be directed towards the south-east, and that in the event of their prolongation, this curvature would be more and more directed to the south, and would increase in the same proportion the difficulty of passing vessels inwards during the prevailing winds.

With reference to the relative value of the water passing down the two branches, he would only say, that he did not consider it an advantage to have a large body of water discharging at the entrance. That was the only disadvantage of the St. George as compared with the Sulina. The more the quantity of water, the greater would be the amount of deposit. But the rapidity of the littoral current, and the greater depth of the sea to the south of the delta, were circumstances which far outweighed the disadvantage of having a larger volume of water passing by the St. George, than was absolutely necessary for the maintenance at its mouth, by means of parallel piers, of a sufficiently wide and deep channel for the navigation.

The two cases of the Danube and the Thames were entirely different; the one discharging itself into a tideless sea and the other into an estuary having a considerable influence of tide. Mr. Hartley believed that if the whole of the silt-bearing waters of the Danube were directed at once to the sea coast, in one unbroken channel, a bar would be formed further from shore, with even a less depth of water than was found at the present time, either at the bars of the Kilia, or the St. George.

Mr. HAWKSHAW,—President,—said, that in most cases the object of constructing piers was to convert into a promontory that which by nature was a bay. When a bar was to be removed, piers were projected seaward; but, in many cases, no Engineer could previously determine with accuracy the extent to which it might ultimately be necessary that such piers should be carried. Although at its commencement a curved pier might be pointed seawards, yet if prolonged sufficiently, it would eventually assume a landward direction. A single pier of that character could not, therefore, be put forward as the general mode of dealing with such cases. He had been called on to report on a single pier which was being constructed at the mouth of the Düna, very similar in form to that at the harbour of Swinemunde. It had been commenced of a curved shape, in order that the current might work against the concave side, and so secure deep water. This method of dealing with the mouth of a river of such a character might answer for a time; but as in most cases, it would ultimately be necessary to carry the piers to points more distant than had been first contemplated, a curved line might prove very inconvenient. Under certain circumstances there might, however, be some difficulty in laying down piers on suitable lines for their ultimate extension; because if so laid down, the extremity of the piers might be left too wide apart for present purposes. Engineers were compelled to adopt such measures as would be beneficial to the present generation, leaving it in many cases, to their successors to prolong, or to modify the works if necessary. In the present day —and he supposed it would continue to be so—their task was not only that of building up, but also that of pulling down. There was great force in the observations which had been made as to the comparative value of upland and tidal waters. From the circumstance that the tidal water operated every day, its scouring power was always in action; whereas upland waters were only energetic after heavy rain, and in dry seasons they were of little avail.

The Paper brought before the Meeting by Mr. Hartley possessed great interest, and had been as carefully considered and compiled, as the works themselves appeared to have been well designed and executed. He hoped that the results of any future works would be communicated to the Institution.

March 18, 1862.

JOHN HAWKSHAW, President,
in the Chair.

No. 1,052.—"Description of Works at the Ports of Swansea, Blyth, and Silloth.[1] By JAMES ABERNETHY, M. Inst. C.E.

IN the following Paper, the Author proposes to give an account of the past and present history of the above ports, and to describe portions of the works connected with them, his object being rather to elucidate general principles than matters of detail.

SWANSEA.—The port of Swansea is situated at the mouth of the River Tawe, on the northern shore of the Bristol Channel, and 38 miles from its entrance. Situated in the centre of an extensive bay, it is partially sheltered from the prevailing winds, by the well-known promontory the Mumbles. This headland bears from the harbour entrance S.W. ¾ W. To the eastward of it there is a roadstead, much frequented by vessels, which affords excellent anchorage, as regards the nature of the holding-ground, but it is exposed to the range of the sea in south-westerly gales. Eastward, the Bay of Swansea may be said to terminate at Milford Point, 3½ miles from the River Neath, the distance across the bay from this point to the Mumbles headland being 6 miles. The entrance to the port of Swansea is exposed from S.W. ¾ W., to S.E. The heaviest seas occur between these points of the compass, when the wind is in a south-westerly direction, or directly up the Channel.

The rise of tide, opposite the harbour entrance, is 27 feet 3 inches at ordinary spring tides, and 20 feet 3 inches at ordinary neap tides. The tide recedes about a mile from the pier heads. At the entrance of the harbour, the depth of water is 23 feet at high water ordinary spring tides, and 18 feet at ordinary neap tides. Both on the flood and on the ebb, the tide sets round the Mumbles into the bay in a circular direction; its mean velocity, on the flood, being 1¼ knot per hour, and on the ebb 1½ knot per hour. In south-westerly gales, the sea sets directly on shore; the direction of the wave being changed after passing the Mumbles, by the retarding influence of the shoal ground, on the western side of the bay. The tide flows up the River Tawe about 3 miles above the harbour entrance, where its further progress is obstructed by a dam called the Forest Weir. The ordinary rise of spring tides at this weir is about 12 feet. The amount of fresh water discharged by the river is trifling, as compared with the volume of tidal water ebbing and flowing between the pier heads. As it runs for its whole length along a narrow valley, with ranges of high hills and mountains on each side, it is subject occasionally to violent floods, which exert a powerful influence in the removal of any casual deposit within its bed. The ordinary maintenance of the channel is, however, dependent on the tidal ebb and flow.

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[1] The discussion upon this Paper extended over portions of two evenings, but an abstract of the whole is given consecutively.

Previous to the year 1791, the port of Swansea consisted simply of a few insignificant wharves, near the mouth of the river, which then ran along the town quays. The entrance being exposed to the direct action of the sea in westerly gales, was at times difficult of access; and a bar existed across its mouth, having a depth of from 16 feet to 17 feet of water upon it, at spring tides. An Act for improving the harbour was obtained in 1792, and the piers, as they at present exist, were shortly afterwards commenced, and were completed in the year 1800, from the designs of Captain Huddart, F.R.S. The eastern pier is 1,340 feet, and the western pier 580 feet in length. (Plate 11, Fig 1. Plan of Swansea Harbour in 1860.) The effect of the construction of the piers was to render the harbour more accessible for vessels of a small class, and to afford shelter within. By the prolongation of the river current, the bar was lowered and driven further seaward, so that in the year 1831, it was reported that there was a depth of 20 feet of water over the bar, at high water ordinary spring tides. In the years 1826 and 1827, Mr. Tennant established a small harbour on the eastern side of the space within the piers called Fabian's Bay. This harbour has a communication with the canal connecting the Vale of Neath with Swansea Harbour. No works of any consequence were executed after the completion of the piers designed by Captain Huddart, until the year 1826, when as the wants of the port were increasing, the necessity for further improvement induced the harbour trustees, in the year 1826, to consult Mr. Telford. In his Report, dated the 5th of February, 1827, he recommended:—First, from the action of heavy floods: That a new cut should be made for the river, in order to relieve the shipping lying in the channel at the town quays. Secondly: The conversion of this new cut and of the old harbour into floats, independent of each other, by locks, with a weir, overfall, and draw sluices, in order that the river might be preserved of any convenient height, "or occasionally driven down so as to clear any obstruction which might be found in its bed." Thirdly:

the direction of the ebbing currents by the formation of slag banks, to affect the bar. Much discussion arose among the local authorities regarding these propositions, and the whole subject was brought prominently under their notice, by the late Mr. Vivian, M.P. In the month of January, 1831, the late Mr. H. R. Palmer, C.E. was consulted by the Trustees. He generally approved of Mr. Telford's plans, but recommended the prolongation of the western pier. This proposal met with much opposition from nautical men, in consequence of its interfering with the ingress of vessels, steam tugs being little used in those days. Public opinion was strongly in favour of Mr. Telford's proposition, for the conversion of the old and proposed new channel of the river into floats; but the late Mr. Henry H. Price, C.E., in a letter to Mr. Vivian the Chairman to the Trust, dated the 17th February, 1831, condemned the carrying out of the scheme; urging that it would silt up the river, deprive the harbour of back water, and increase the bar. Mr. Price's letter was followed by numerous opinions and reports, from various other Engineers, including Mr. Brunton, and Mr. Roger Hopkins, who suggested modifications of Mr. Telford's plan. Finally, in the year 1831, Mr. Jesse Hartley recommended the conversion of the town reach of the river into a dock and half-tide basin, the formation of a new cut for the river, and its 'canalization' by the construction of a weir across its mouth, with striking planks which could be immediately lowered when any sudden emergency from floods might arise. In August of the following year, he was called upon to reconsider this Report, when he adhered to his former plan, and recommended, in addition, the generally deepening of the harbour, by dredging. Fortunately, none of the various works recommended for the canalization of the river, were executed; but a new channel, now known by the name of the New Cut, was commenced in 1840, and finished in 1844, at an expense of £23,000. The effect of this work, was materially to lessen the risk to the shipping lying in the Town Reach, or harbour, during floods, and to give the outgoing current a better direction, and greater force, by which the navigable channel was materially deepened and improved. In 1845, the late Mr. Rendel was consulted, relative to floating dock accommodation. Without expressing any decided opinion, as to the advisability of transforming the river into a floating dock, he recommended, in the first place, the construction of an entrance with a double cill, as a provision for canalizing the river itself, or the old Town Reach, as might be found desirable at a future period. The masonry alone of this work was executed. About four years afterwards the Author was first consulted on the same subject; and in his Report to the Trustees, dated February 1849, he recommended the old Town Reach as the best site for the formation of a dock: first, on account of its proximity to the town; secondly, because the New Cut was a more direct and effective channel for the river; thirdly, because the Author was of opinion, that any interference with the new channel, which would prevent the free influx and reflux of the tide, would be extremely prejudicial to the harbour entrance. In arriving at this conclusion, he considered, that although the land floods were the active agents in removing deposits from the channel, the volume of tidal water was nevertheless the chief maintaining power; that every facility should therefore be given to aid the tidal flow by deepening the bed of the river; and that in proportion as the bed of the river was lowered, the entrance channel would be deepened. After various negociations, the construction of a dock and half-tide basin, of the respective areas of 11 acres and 2¾ acres, was agreed upon and carried out. The entrance to the half-tide basin is 60 feet in width, with a depth over the cill of 25 feet 6 inches at high water of ordinary spring tides. The lock entrance to the dock is 160 feet long, and 56 feet wide, with a depth over the cill of 22 feet 6 inches at high water of ordinary spring tides. A small lock connects the Swansea Canal with the Float, and there is also a lock for small coasters at the head of the Float, by which a communication is effected with the various works on the banks of the river above. A small dock leading from the float, with an extensive range of warehouses round its margin, was also constructed under the direction of the Author, for his Grace the Duke of Beaufort.

The works of the lock and float were commenced in November 1849, and were completed in December 1851, under the immediate superintendence of Mr. George Abernethy. (Assoc. Inst. C. E.) Those of the half-tide basin and locks at the upper end of the float were commenced in 1856, and were completed early in 1861. The total cost of the works, exclusive of the quay walls, which had formerly been constructed, was £95,688, divided as follows:—

1st, Entrance lock, return and wing walls .	£23,000
2nd, Outer basin and lock in upper part of float	28,014
3rd, Lower entrance and half-tide basin .	33,560
4th, Hydraulic machinery	11,114

In addition to these works, the river was straightened and deepened by dredging, from the New Cut entrance to the pier heads, so as to give greater volume and better effect to the outgoing tidal current. The bed of the New Cut was also deepened, and quay walls were built along its sides. By the combined effect of these works, an increased depth of 4 feet has been attained since the year 1850, throughout the whole of the entrance channel. There is nothing in the construction of the float demanding special notice, except the application of hydraulic power to the existing machinery for opening and shutting the gates. In the year 1853, the Author consulted Sir William Armstrong on that point, and in the year 1856 hydraulic power was first applied to work the existing hand-gear of the lock by shafting; a system which was afterwards carried out, in a more perfect form, in other portions of the dock works, as will hereafter be described. The execution of the general works was attended with some difficulty, in consequence of a large portion having to be performed by tide work, with as little interruption as possible to the trade of the port. The foundations varied from hard concreted gravel, to soft sandy clay, which extended to a considerable depth. From their peculiar character it was anticipated that numerous contingencies might arise, and in consequence the principal works were not carried out by contract, but were executed under the direction of the resident Engineer.

The most important work connected with the port of Swansea is the range of floating dock accommodation called the South Dock (Plate 11, Fig. 1). It is partly formed on the foreshore of the sea, beyond high water mark, in a position somewhat similar to that of the South Dock at Sunderland. Attention was first directed to this site in 1846, when the general question of floating dock accommodation attracted the notice of the local public, and the late Mr. Brunel was consulted by his Grace the late Duke of Beaufort. In his Report made in October 1846, he condemned, strongly, the project of converting the river into a float, and recommended that any additional dock accommodation should be provided on the western side of the harbour, as being the most weatherly and sheltered, during the prevailing winds; and possessing superior commercial advantages, from its proximity to the town.

An Act for the construction of the South Docks, according to a design of Mr. Page (M. Inst. C.E.), was obtained in 1847, and in the year 1850, the Author was called upon to make the necessary detailed plans and specifications for the execution of the works. They consist—first, of a trumpet-mouthed entrance basin, with an area of 3 acres; secondly, of a half-tide, or outer dock entrance, 70 feet in width, with a single pair of gates, having a depth of water over the cill of 24 feet at high water ordinary spring tides; thirdly, of the half-tide basin, or outer dock, of an area of 4 acres, with a depth of 25 feet 6 inches at high water of ordinary spring tides; fourthly, of an entrance lock, 300 feet in length and 60 feet in width, with an average depth of water over the inner cill of 22 feet 6 inches at high water ordinary spring tides, divided by intermediate gates, so as to form a greater or smaller lock; and, fifthly, of a dock of an area of 13 acres, with a depth of water of 24 feet below the general level of high water ordinary spring tides.

The first section of these works was carried out under the direction of Mr. George Abernethy (Assoc. Inst. C.E.), as resident Engineer, with Mr. Joseph Pickering as contractor, until the year 1855, when the works were suspended for want of funds. They were resumed under the direction of Mr. William Neill as resident Engineer, and Mr. William Tredwell, as contractor, in 1857, and completed in 1859, at a total cost of £169,073 divided as follows:—

	£.
1. Trumpet mouth	9,628
2. Single entrance	12,632
3. Outer basin	21,300
4. Lock	40,443
5. Dock	69,086
6. Hydraulic machinery	15,984

As before remarked, the docks are formed on a site partly reclaimed from the sea. The excavations were of a varied character, and for the most part consisted of—made ground and boulder gravel, 6 feet; peat with leaves, trees, and vegetable remains, 2 feet; blue clay, containing shells, 8 feet 6 inches; blue clay, varied with three layers of peat containing leaves and trees, 8 feet; and then of hard boulder gravel and clay to the bottom of the dock.

In executing the works, one of the first operations was the formation of the embankment for the purpose of excluding the sea. Careful tidal observations had shown, that the set of the tides and the main action of the sea were westward towards the Mumbles headland. Keeping this fact in view, the embankment was formed in the following manner: timber groynes were constructed at intervals of 1,500 feet to the full extent of the proposed embankment; and then the rough boulder gravel, found immediately under the sand and the made-ground, was tipped between the groynes, at the seaward end, the lighter material being deposited within, and towards the landward end. The action of the sea and the tide removed the lighter portion of the gravel, and carried it to the westward, leaving the heavier portion and the boulder stones, which gradually formed a shingle beach of great depth, as a facework to the embankment. This beach, formed into its ultimate angle of repose, has proved an effective barrier to the encroachments of the sea. By using the clay and the peat portions of the excavations, in the centre of the embankment, something like a puddle dyke was formed, and only ordinary means sufficed to keep down the accumulation of water within the works.

A sufficient portion of the sea embankment having been completed, the masonry of the dock walls was next proceeded with. These walls are shown in section in Plate 11, Fig. 2. They consist of rubble masonry, with coursed rubble facework to a height of 2 feet below the general level of the surface of the water in the dock. Above this level, they are faced with ashlar, projecting 3 inches beyond the rubble facework.

Great care was taken in the preparation of the mortar, which was composed of Aberthaw lime, burned in kilns on the works, and well ground by revolving stones. One part of slacked lime was mixed with one part of clean sharp sand for first-class mortar, and one and a half of sand to one part of slacked lime was used for second-class mortar. The walls were backed up with the lightest and driest material, in layers forming an angle from the wall; and rubble drains with pipes for carrying off spring, or upland waters, were placed in the walls at such intervals, as were found desirable. Owing to these precautions no failure has taken place, although the walls have been subjected to a severe test, inasmuch as they were nearly all completed prior to the suspension of the works in 1855, and pending their resumption in 1857, the dock and outer basin, from drainage, land springs and percolation from the sea, had become filled with water nearly to the spring tide level; the water being retained in the dock and basin, by an embankment, serving as a dam, across the outer entrance. Before re-commencing the works, the water was gradually lowered from the surface, by overfalls, connected with a culvert and sluice in the embankment, at the rate of from 2 inches to 3 inches per day.

The details of the lock and entrance are shown in Plate 11, Figs. 2 to 17 inclusive. They are constructed, generally, of elliptical inverted arches of rubble, with bond stones, and ashlar quoins, ashlar floors, or platforms, of coal measure sandstone, found in the neighbourhood. The pointing cill stones and hollow quoins are of greenstone, and syenite, from the Carling Nose and Barnton Mount quarries, near Edinburgh. The cill stones are carefully toothed and bonded into the floor stones, so as to avoid a long straight joint. The recess and side walls are of rubble, with ashlar facework in the upper portion, in all respects similar to the dock walls; but the wing walls are faced throughout with ashlar. The filling and discharging culverts are 4 feet in diameter, and are constructed of brickwork, of superior quality. The sluice frames and paddles are of cast iron, faced with brass, carefully planed. The paddles are raised and lowered by hydraulic power.

There is nothing special in the construction of the lock and entrance gates. The details of one pair are shown in Plate 11, Figs. 18 to 29 inclusive. The heel mitre posts and the lower rib are of the best teak and English oak, and the ribs and planking of pitch pine. The contractor had the option of substituting the hardest and best quality of greenheart, or of Honduras mahogany. The Author, in 1849, having constructed the lock gates at Aberdeen of the latter timber, believes it to be a good substitute for either greenheart, or oak. Across the lock there is a swivel bridge of one leaf, worked by hydraulic machinery. It consists of two wrought iron tubular girders, with a superstructure fitted for railway, or road traffic. The form and dimensions of this bridge are shown in Plate 11, Figs. 3 and 4.

There being no backwater for the supply of the dock, the waste from lockage is supplied by a steam engine of 24 H.P. and a centrifugal pump, made by Messrs. Easton and Amos. These are capable of discharging, with a lift of 5 feet, 720,000 gallons of water per hour, a supply which has been found more than ample for the purpose.

The successful application of hydraulic machinery for working the usual hand gear at the float lock, and at the lock of Newport Dock, where the gates were much heavier, determined the Author to adopt a similar system at the new dock entrance, as in case of any accident happening to the hydraulic machinery, the usual means are always available. It being of great importance, in the shipment of Welsh coal, that as little breakage as possible should take place, the Author consulted Sir William Armstrong, as to the construction of the hydraulic drops, or hoists. It was necessary that they should deliver the coal, into the hold of any class of vessel, immediately over the hatchway, and at the same time that they should be suited to the varying size of the broad-gauge coal waggons, which when loaded weigh from 14 tons to 19 tons. Sir William Armstrong recommended that the different machines employed for opening the gates, bridges, and sluices, the capstans for hauling vessels in and out of dock, the discharging of ballast, the loading of coals, and the shipment and discharging of general cargoes, should be worked upon his hydraulic system, with accumulators equivalent to an effective pressure of 750 lbs. per square inch. Three high pressure direct acting steam engines are employed, of 80 H.P., 30 H.P., and 12 H.P. respectively. The distribution of power is regulated by self-acting arrangements, in connection with the accumulators, apportioned, in each case, to the powers of the machines at present erected. At the float lock, each line of shafting is driven by a small water pressure engine placed near the middle; but owing to the length of the lock at the new dock, and other minor circumstances, the line of shafting is broken, and is driven by two separate hydraulic engines on each side of the lock (Plate 11. Fig. 3). The whole of the mamachinery, together with the capstan heads for working the gate by hand, in the event of any accident happening to the driving power, is placed under the ground level, and is covered by cast iron plates. The hydraulic engines are about 8 H.P. each, and are only employed, in this case, for working the gate crabs and the capstans, which latter are placed at the extremities of the lock. These capstans can be readily disengaged and be worked by hand-spikes, in the ordinary way. The time employed in either opening, or closing, the gates, is about two minutes and a half, which is the shortest period consistent with the safety of the gates. The gate crabs are provided with fluted rollers, of sufficient length to take on one layer of chain; and a brake commanded by a handle is attached to each crab, to prevent the slack chain from running down. The engines may be put in motion by a man stationed at any one of the gate crabs, or capstans, of the line of shafting which they respectively drive. The sluices are worked directly by means of a piston and plunger placed immediately above them. They are provided with a small force pump, to be worked by hand in case of accident. The wrought iron swing bridge is turned by means of two hydraulic cylinders, working in opposite directions, and attached to a drum, beneath the bridge, by means of a chain. The bridge can be opened, or shut, in one minute and a half; it is also provided with hand gear.

The ballast cranes, which are distributed round the dock, can each discharge from 350 tons, to 400 tons, in the day. The ballast is lifted out in tubs each capable of containing one ton, and is deposited at once in railway trucks. The coal is brought up for shipment in two distinct classes of waggons, for each of which special arrangements are made. In one class, the coal is carried in end-tipping waggons; in the other the coal is packed into wrought iron boxes, having false bottoms, each holding about 2½ tons. Four of these boxes are placed upon one truck. Of the two systems, the latter is the more perfect for avoiding the breakage of the coal. The speed at which the coal can be shipped, by either of these systems, is about equal. Both will deliver it on board faster than the trimming can be accomplished in the hold of the vessel. The quantity of coal that can be shipped by each machine is about 1000 tons per day.

Plate 12 (Figs. 2 to 6 inclusive) shows the machinery for shipping the coal. The machine for delivering the coal in boxes, is placed above that for discharging the end-tipping waggons; and both are under the command of one man. This combination has the great advantage of permitting a cone of coal to be formed in the hold of a vessel on first loading, by means of the boxes, which are lowered through the hatchway, and deliver their coals without any fall, and upon this cone the remainder of the coal can, with great saving in breakage, be delivered from the shoot in connection with the waggon-tipping arrangement. The coal is brought on the hoist at a level of 21 feet above the quay, a slight downward inclination being given in the rails leading to it. In order to command the longest class of vessels, the waggon hoists have a range of lift of 6 feet above the level of the upper rail, and are capable of lowering waggons 15 feet below the level of the rails on the viaduct. The operation of lifting and of lowering the waggons is performed by a direct acting ram A A, attached to the underside of a wrought iron cradle B, upon which is placed a traverser C, carrying a tipping frame D. The traverser is employed in placing the boxes vertically on the trucks, under the lifting chains of the combined hoist, and for running the empty waggons and trucks on to the 'return' line, which at the point of the hoist stands 14 inches above the 'full' line. The rails upon which the traverser runs have an inclination towards the return line. When therefore the catch E, which holds the traverser to the cradle, is liberated, the traverser runs down by its own gravity; its speed and the distance which it travels being checked by the exhaust valve of the ram, which is employed for hauling the traverser back to the cradle. The tipping-frame D, which works upon a hinge at the front end, is lifted and lowered at the other end by a ram D′ oscillating upon the cradle. The head of the ram is jointed in the direction in which the traverser runs, so that it is easily engaged, or disengaged from the tipping-frame. The wrought-iron shoot G, suspended in front of the hoist, is of sufficient capacity to hold an entire waggon-full of coal. It can be raised, or lowered to any height, or angle, to suit the various-sized vessels, and the sliding down of the coal—an operation which is performed by attaching the chains holding the shoot to the cradle, which is of superior gravity. Two doors for regulating the discharge of coal are placed at the end of the shoot.

The operation of discharging the waggons is thus performed:—A full waggon is run on to the rails of the tipping frame; the cradle is then either lifted, or lowered to the level of the shoot, as the case may be. The catches of the waggon door are knocked out, and the pressure applied to the tipping ram. The buffers of the waggon rest on the end of the shoot during the discharge, to prevent any coal from falling from the waggon on to the shoot. On lowering the empty waggon, the cradle is lifted, or lowered, to the point where the rails of the traverser on the cradle and the staith meet. The catch which secures the traverser to the cradle is then liberated, and the waggon is allowed to run down to the return line, on to which it is pushed. The traverser is then hauled back to the cradle by a ram, and is lowered to the point, defined by self-acting stops, where the loaded waggons are taken on. The waggons with the boxes are run on to the cradle. Three chains, passing from the lifting and tipping cylinders over the jib, I, I′, I″, K K′ K″, are secured to one of the boxes, the centre, or tipping chain being made fast to the body of the box, and the two outside, or lifting chains, to chains permanently attached to the folding doors, constituting the bottom of the box. The box is then lifted clear of the truck, and the jib M, by means of the turning cylinder, ram and chain L L′ L″, is allowed to turn out to the required distance for hanging the box vertically over the hatchway of the vessel. The box, whilst in the act of turning, and as soon as it is clear of the truck, is rapidly lowered through the hatchway until within 2 feet of the bottom of the ship, or of the coal already deposited. The tipping chain is then slacked, and the lifting chains still running down, permit the doors of the box N to open and deliver the coal gently. Pressure is then applied to the lifting cylinder, to which both the outside chains are attached, the box is drawn up quickly, turned back, and deposited upon the truck. Another box is then attached and emptied in the same manner. When all four boxes are discharged, the truck is allowed to run down to the return line, is taken off, and the traverser is brought back ready to receive another load.

As regards the amount of work performed by the hydraulic machinery and its cost in the year 1860, careful observations were made on these points; but inasmuch as the engine power was never kept at full work, the estimate then arrived at was beneath its capabilities. The results will serve, however, as data for defining the actual work which can be accomplished. Tables 3, 4 and 5 appended to this Paper (pp. 330-334) give the details upon which the following Tables, 1 and 2, are based:—

TABLE 1.

STATEMENT of the actual work performed by the Hydraulic Machinery of the South Docks, and the Cost of the Power per Week, for the Year ending October, 1860.

Nature of Work.	Quantity of Water in Cubic Feet required.	Per Week.	Cubic Feet in One Week.	Total Cubic Feet in One Week.
Entrance gates to open and shut	58	13·6 tides.	788·8	
Entrance capstans to wind 300 yards . .	In one revolution of Engine, ·132	900 revolutions of Engine × 13·6 tides.	1,615·7	
Lock gates to open and shut, side sluices and bridge	63	28 lockages.	1,764·0	
Capstans at lock to wind 600 yards . .	In one revolution of Engine, ·132	1,800 revolutions of Engine × 13·6 tides.	3,231·4	7,400
Cranes—lifts . . .	In one lift, 3·5	2,000 lifts.	say 7,000	7,000
Coal drops—combined drop	In four lifts of boxes, 20	190 waggons.	3,800	
Waggons drop . . .	In one lift, 15	190 waggons.	2,850	6,650
Effective quantity of water required per week, cubic feet . .				21,050

The cost for engine power is shown, by Table No. 5, to amount to £22. 16*s.* 1*d.* per week, being at the rate of 0·26 of a penny per cubic foot of water used for pressure.

The cost of working the gates, cranes, and coal-drops per week will therefore be as follows:—

	d.	£.	*s.*	*d.*
7,400 cubic feet of water for lock and entrance	at 0·26 per cubic foot	= 8	0	4
7,000 ditto for cranes . . .		= 7	11	8
3,800 ditto, combined coal-drop .		= 4	2	4
2,850 ditto, waggon-drop . .		= 3	1	9
		£22	16	1

				No. of Tons lifted.
The cost for working the cranes is at the rate of . .	0·9 of a penny per ton			2,000
Ditto, combined drop. .	0·5	,,	,,	1,900
Ditto, waggon-drops. .	0·4	,,	,,	1,900

These last results are attained by dividing the number of tons shipped and lifted per week, by the total cost of each item.

The lock for the North Dock is not included in this statement, as it was not used, during the progress of the half-tide basin works; but the quantity of water required to work it is 4,108 cubic feet per week, allowing for the use of the lock twenty-eight times per week, for 600 yards wound by capstans per tide, and for the bridge being opened and shut forty times per week.

Table 2.

Statement of the work that can be performed by the 80 H.P. Steam-engine for working the Hydraulic Machinery, and the estimated cost of the same.

The 80 H.P. steam-engine, at its maximum speed, forces 1,644 cubic feet of water per hour. But it is assumed that 20 per cent. ought to be deducted for leakage in the pipes, valves, packings, and for waste. This would make the effective quantity of water forced per hour equal to 1,315 cubic feet. The quantity of water pumped per week, working at the rate of 12 hours per day, and 4 hours on Sunday will therefore be:—

Cubic Feet.		Hours.		Days.		Cubic Feet.
1,315	×	12	×	6	=	94,680
1,315	×	4	×	1	=	5,260
						99,940

Say 100,000 cubic feet.

The estimated cost of engine power for pumping the above quantity is £30 per week, being at the rate of 0·072 of a penny per cubic foot of water. It will be seen by Table 1 that the quantity of water required to work the gates, bridges, sluices, and capstans is, for the South Docks, 7,400 cubic feet per week; and for the North Docks, 4,108 cubic feet per week, equal together to 11,508 cubic feet per week. But in order to allow for a large increase of trade, it is assumed that there will be required 20,000 cubic feet per week:—

	Cubic Feet.
Total quantity of water forced per week . .	100,000
Deduct for working the gates, bridges, sluices, and capstans in the North and South Docks . .	20,000
Leaving available for working the cranes and coal-drops	80,000

If this quantity be divided equally between the cranes and the coal-drops, the proportion of water and the corresponding work that can be performed will be:—

	Tons per Week.	Water used per Ton. Cubic Feet.	Cubic Feet.
For working the gates, bridges, sluices, and capstans at the North and South Docks . . .			20,000
Discharged by cranes . .	11,428	3·5	40,000
Discharged by coal-drops, being a maximum . .	20,000	2	40,000
			100,000

The cost of supplying power for working the gates, cranes, coal-drops per week will then be as follows:—

	d.		£.	*s.*	*d.*
20,000 cubic feet of water for lock and entrance . .	at 0·072 per cubic foot.	=	6	0	0
40,000 ditto for cranes . .		=	12	0	0
40,000 ditto for coal-drops .		=	12	0	0
Total cost per week . .			£30	0	0

The cost for working the cranes will be nearly ¼*d.* per ton, and for the coal-drops about ⅐ of a penny per ton. This is simply the cost of supplying the hydraulic power.

In conclusion, the commercial effect of the construction of the dock works and of the general improvement of the harbour may be briefly noticed. The Port of Swansea, being the great emporium of the copper trade, has, for a long time, been frequented by vessels of a superior class. Up to the year 1850 it was merely a tidal harbour, and vessels constantly received injury by taking the ground on an uneven bottom, so that few shipowners would permit vessels of a superior class to frequent it. During the year 1851, at the period of the completion of the first, or north dock, the tonnage of the vessels frequenting the port was 269,454 tons, while the tonnage in 1860 amounted to 582,355 tons. During the year 1861 the foreign tonnage has increased 16 per cent.; and, as the port is now about to be connected, more directly, with the steam coal district, by means of the Vale of Neath Railway, and with the great iron-producing country around Aberdare and Merthyr, and both by broad and narrow gauge railways, with the heart of the kingdom, it bids fair to become the most important port in the Bristol Channel, being situated nearest to its mouth, and below all the most difficult portions of the navigation.

Blyth.—A detailed description of the works constructed at the entrance of the Port of Blyth has been already given in the Papers on "Breakwaters," Parts I. and II., by Mr. Michael Scott, M. Inst. C.E.[1] But the Author desires, for the information of the Institution, to describe the present state of the sea, or entrance channel, as compared with its original condition, as an exemplification of the effects produced by the construction of the breakwater and other works, combined with the operation of dredging. The channel at low water in the year 1854, previous to the commencement of any works, was extremely tortuous, and in many places dry, at spring tides. Generally, there was not more than a foot of water within it, and a spit of sand extended from the southern side nearly across the entrance, which presented a dangerous obstruction to shipping during gales of wind. The channel, for its entire length, of 4,500 feet, ran parallel with a lee shore, exposed to the direct action of the north-easterly seas, and in consequence scarcely a winter passed without vessels being stranded and wrecked on the beach on the southern side, while the estuary, within the river-mouth, forming the harbour, was exposed to the run of the sea during on-shore gales. To remedy these evils, the Author, in 1853, designed the works shown in Plate 13, Fig. 1, and an Act for their construction was obtained in 1854. They were commenced in 1855, and were completed during 1861 at a total cost of £67,320, divided as follows:—

	£.
1st. Eastern breakwater, 4,500 feet in length . .	37,000
2nd. Western half-tide training wall, 4,000 feet in length	16,570

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[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xviii., p. 72; and vol. xix., p. 644.

	£.
3rd. The straightening and deepening of the channel by dredging	13,750

In designing these works, the Author had in view the following objects:—First. To afford protection to vessels entering and departing, from the action of the sea in north-easterly gales. Secondly. To confine and direct the outgoing current, so as to afford sufficient scouring power to maintain the increased depth obtained by dredging. And, thirdly. To prolong the outgoing current seaward, so as to bring the detritus carried by it within the influence of the tidal current along the coast. The Author was guided by experience obtained at Aberdeen Harbour, the entrance to which is similarly situated to that of the Port of Blyth, and the results of the works executed are the same in both cases. Under these circumstances it may be instructive to notice, briefly, the past and the present state of the entrance to Aberdeen Harbour. Its condition in 1792, previously to the erection of any works, is shown in Plate 13, Fig. 2, from a survey taken under the direction of Mr. Smeaton. By the action of north-easterly seas on the long extent of beach to the northward, a great quantity of sand was driven into the mouth of the harbour, and at the point where the outgoing current lost its force in the ocean, a bar was formed, having upon it only 2 feet depth of water, at low water of ordinary spring tides. Under Smeaton, and subsequently under Telford, with the late Mr. John Gibbs, as resident Engineer, the present North Pier, 1,850 feet in length, was completed in 1809. Its effect was, that the bar at the entrance only formed under certain conditions of winds and freshes, and then with a considerably increased depth of water over it. The Author became Engineer to the Harbour trust in the year 1841, and shortly afterwards recommended that dredging operations should be executed, with a view to obtain an increased volume of tidal ebb and flow in the harbour, and the channel of the River Dee; and that a better direction should be given to the out-going current, by embankments and other works, in connection with the entrance channel. Between the years 1841 and 1851, one million tons of material were removed from the bed of the harbour by dredging, exclusive of large quantities of boulder stones laid bare from time to time by the constantly increasing action, of the out-going current. The result has been, the entire removal of the bar, which may be said to have had no existence since the year 1851, as the bottom of the channel now forms a plane gradually inclining seaward, with a depth of 10 feet at low water of spring tides, between the pier heads. (Plate 13, Fig. 3.)

The same result has followed the construction of the works at Blyth. The outgoing current has been increased to a velocity of 5 knots per hour at its greatest strength, whereas formerly it was lost immediately on passing the line of the foreshore. The bar, or spit of sand, across the entrance is entirely removed, and there is now a depth of 8 feet, or 9 feet, at low water, immediately opposite the breakwater. The depth throughout the channel has been increased 4 feet, and vessels, after passing within the breakwater, are effectually protected from the action of north-easterly, or on-shore gales.

SILLOTH.—The port or harbour of Silloth is situated on the margin of a small bay, on the southern side of the Solway Frith, 12 miles from Port Carlisle, and 30 miles from the mouth of the estuary (Plate 14, Fig. 1, General Plan of Solway Frith). For centuries Silloth Bay has been known as a place of anchorage, and haven of safety, for an extensive range of coast. Situated below all the difficult and intricate portion of the navigation of the Solway Frith, with deep water close in-shore (an advantage possessed by no other harbour on the Cumberland coast), it was obviously a most desirable site for the construction of a commercial harbour, and had been so considered in the locality for a long period. In the year 1854, several enterprising local gentlemen, headed by Mr. William Marshall, M.P., obtained an Act for the construction of floating docks and of a pier, and other works, in connection with a line of railway, to form a junction with the existing Port Carlisle Line, which would bring the projected port within 21 miles of the city of Carlisle. The Act was obtained, after a severe Parliamentary struggle, the Bill having been rejected in the previous session, chiefly from the weight of engineering and nautical evidence against the scheme. This opposition was upon the whole beneficial, as it resulted in the selection of an improved site, against which, however, equally strong objections were urged, and the Author is of opinion, that useful practical information may be derived from a consideration of the main objections to the scheme, and the results which have followed the progress and completion of the works. The general design for the works is due to Mr. John Hartley, M. Inst. C.E., whose other duties necessitated his resignation as Engineer after the passing of the Act, and who was succeeded by the Author. The various works (Plate 14, Fig. 2) were carried out in accordance with the general arrangement of the original design; this consisted of:—

First; A pier, or jetty, on the seaward side of the dock entrance, 1,000 feet in length.

Secondly; An entrance channel parallel with the jetty, forming a slight angle with the foreshore, 100 feet in width at the bottom, with slopes of 6 to 1, having a fall of 2 feet 6 inches in its entire length, the bottom of the channel being generally 16 feet below the level of the adjoining beach.

Thirdly; An embankment on the foreshore, projecting 400 feet beyond high-water mark, and enclosing the entrance to the dock, 60 feet in width, with 24 feet of water over the cill at high water of ordinary spring tides, provided with reverse, or sea-gates for protection during gales.

And Fourthly; A dock of an area of 4 acres, with a depth of water 25 feet 6 inches at the general level.

The objections which were urged against the scheme in Parliament, and even until a recent date, were:—That the navigable channel up to Silloth was exceedingly liable to change, and might eventually remove altogether to the Scotch side of the estuary; that the projected pier, although of open pile work, would act as a groyne, and cause accretion on the foreshore; that the proposed entrance channel to the dock could not be maintained, and that it would eventually fill up to the level of the adjoining beach; and that if formed, the dock entrance could not be safely approached by vessels, during westerly gales; and, that as regarded the construction of the dock, the excavations consisting of sand and open gravel, full of land and sea water, the works could not be kept dry at any ordinary expense; and that the bottom of the proposed dock in many places being quicksand, no efficient foundation for the proposed works could be obtained. Before proceeding to consider these objections, it is necessary to describe generally the features of the estuary.

On reference to the general plan of Solway Frith it will be observed, that immediately above Silloth Bay, and to a certain extent below it, the estuary is obstructed by extensive sand banks, dry at low water, which divide its upper portion into two channels, termed the Scotch and English Channels. The latter alone is navigable to Silloth, and to the upper portion of the estuary. Its low-water channel forms the mouths of various rivers, such as the Annan, Eden, Esk, Wampool, and Waver. The estuary rapidly increases its width in its progress to the sea, being 1½ mile wide opposite the port of Annan, 7 miles wide opposite Silloth, and 23 miles wide near its mouth opposite Workington. The tide rises at its mouth, and at Silloth, 28 feet at springs, and 16 feet at neaps. A bar exists across the channel 6 miles below Silloth, having on it 11 feet at springs and 18 feet at neaps, which gives a depth at high water of 39 and 34 feet respectively. With such a rise of tide, the rapid contraction in the width of the channel, and the obstruction caused by the sand-banks, what is technically termed a bore, takes place, the tide rushing with a head of water over the numerous shoals immediately above Silloth. The main volume of tide runs parallel with, and close to the English shore, to that point; after which it passes, but in the same direction, across to the Port of Annan. At the mouth of the estuary the mean velocity at spring tides is 3½ knots, both on the flood and on the ebb. In Silloth Bay the velocity is respectively 5 knots and 4½ knots.

From authentic information, derived from ancient charts, the navigation at Silloth Bay appears to have remained unchanged for a long period. The anchorage within it is good holding ground, being sand with clay beneath, and it is sheltered from the action of the heavy westerly seas by the 'Silloth' and 'Robin Rigg' sandbanks, which rise to a height of from 8 feet to 10 feet above the low-water level. Such being, generally, the principal peculiarities of the tidal and other features of the site, it is now proposed to notice the various objections urged against the Silloth scheme, and the results which have followed the completion of the works. As regards the first objection, looking at the line, and direction of the coast, on the north, or Scotch side of the estuary, and noticing the projecting promontory of Southerness, which forms a barrier to the upward flow of the tide, and causes on the ebb the formation of the Barnhourie spit, or sandbank, it is obvious, that the flowing current must always be deflected to the English side, and there form the principal navigable channel. The changes which take place in the estuary are in its upper portion, immediately below Annan Point, and they are caused by the influence of the land freshes, which occasionally cut a channel to the northward, between the Powfoot Sand and the Silloth Bank. But this channel when formed, becomes gradually very tortuous, arising from the deposit within it, caused by the ingoing tide, and the consequent deflection of the outgoing current. When the channel becomes so tortuous, and lengthened, as to obstruct the tidal flow beyond a certain limit, it at once cuts a direct and new passage for itself. This is a constantly recurring process, and it takes place in other estuaries, of a similar character, as, for instance, in Morecambe Bay, at the mouths of the rivers Kent and Leven. By embankments and training works, at proper points, these defects have occasionally been remedied, and the Author is of opinion, that the first objection to the Solway navigation below Annan Point, would be permanently removed by the construction of a training work below, as is shown at A on the general Plan (Plate 14, Fig. 1). The effect of this he believes would be to form an accretion on the upper part of the Powfoot Sand, and the constant maintenance of a straight navigable channel from Annan to Silloth.

As regards the second objection, namely, the effect of the jetty on the foreshore; although that structure consists of open pile work above the level of the adjoining beach, it has caused a deposit of sand above and below; but this deposit, from the observation of two years, appears to have reached its maximum. Yet even this slight accretion indicates the care that should be exercised in projecting solid works from the foreshore of an estuary, on any sandy coast, as an entrance to ports.

As regards the entrance channel, it has proved successful, and its maintenance is no longer a matter of doubt. Its depth and its sectional area remaining the same as on its first formation two years ago. Any deposit is easily removed by occasional sluicing, before and near to the period of low water. The Author attributes its conservation to the following causes. The tide flows into and rises more rapidly in the Cut than over the adjoining beach. When the whole is covered to the level of the dock entrance, the set of the tide, from the direction of the shore below Silloth Point, is at an angle with the foreshore, and towards the end of the jetty. A great portion of the deposit is brought in by the flowing tide, and the small amount of deposit brought into the channel at a later period, and by the ebb, is removed by the outgoing current from the channel, aided occasionally by sluicing from the dock.

With respect to the concluding objection as to the construction of the dock;—By means of wells sunk on the site of the works, and a moderate degree of pumping power, the sand and gravel of which the excavation consisted were drained, and careful sheet piling, and beds of concrete, afforded foundations for the various works without any difficulty. To prevent percolation from the dock, the excavation from the seaward end was carried to an extra depth, and the space was filled in with clay which cropped out beneath the gravel at the upper end of the dock. The sea was excluded from the entrance by a cofferdam projecting from and abutting upon the timber wharfing, or framework of the embankments. This dam consisted simply of two rows of whole timber piles, 5 feet apart from centre to centre, connected by tie-bolts and external wale pieces, lined, inside, with 3-inch planking, the space between being filled with clay puddle. The clay was carried down to a depth of 5 feet below the level of the adjoining foreshore, and as the bottom of the excavations within was 26 feet below this level, the exclusion of the tide was dependent upon the sandy beach in front of the dam. This was found quite efficient for the purpose; the only precaution taken being to drive a row of sheet piles at a distance of 18 feet within the cofferdam to keep the sand from falling into the foundation trench. Upon the whole, the construction of the dock works, instead of being a matter of difficulty, was easier than that of any other similar work upon which the Author has been engaged.

The entrance gates, cranes, and coal-hoists are worked with hydraulic machinery, similar to that of the docks at Swansea. The coal-hoists, however, form an exception which deserves special notice, as involving a question of the relative capabilities and advantages of a high, or low level system for loading coal. No doubt there are sites where of necessity the former system must obtain. But in cases similar to that at Silloth, and the parallel case of Newport, in Monmouthshire, also under the Author's direction, all the advantages are in favour of the low-level system, both for convenience and economy. In these cases the railways approach the docks on the level of the quays, and the formation of viaducts, to attain a high level, would have materially interfered with the adjoining streets and property, and would have been costly. By adopting the low-level system, the cost of high-level erections is avoided, siding accommodation can be afforded with comparatively much greater facility, and at less cost, and the quays are left unencumbered for general traffic, the spaces required for the hoists being only 12 feet in length, by a breadth of 20 feet from the front of the quay wall. As regards quantity, 1,000 tons per day can be put on board by the drops; in fact, the limit is the amount that can be trimmed in the hold of the vessel. The cost has been found to approximate to that at Swansea, namely, ¼*d.* per ton. This might no doubt be reduced if the machinery was fully employed.

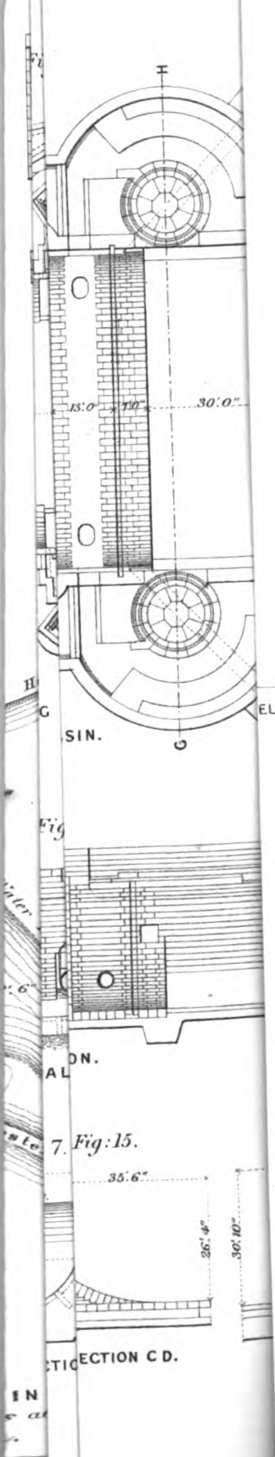
The details of one of these hoists are shown in Plate 14, Figs. 3 and 4. They are constructed to receive both tipping and hopper waggons. The rails run at right angles to the hoist, and turntables are used for bringing up the waggons to the cradle of the hoist. The hopper waggons, on being raised to the required height for discharging, deliver their coals on to a shoot, contained within the cradle, and which is brought into line with the outside shoot. A self-acting flap, for carrying the coal, passing from one shoot to another, is attached to the cradle. The outside shoot is provided with doors, and is raised and lowered by an attachment which can be made to the cradle. The end tipping-waggons, on being lifted to the level at which the shoot may be placed, are tipped by means of a cylinder and ram attached to the side of the hoist, and connected by drums, shafts, and chains, to the tipping-frame. The heaviest waggons lifted by these hoists weigh when loaded 13 tons, and the greatest height to which they can be raised is 19 feet above the quay level.

The works at Silloth were commenced in the year 1856, and were completed in 1859 at a total cost of £122,000, divided as follows:—

	£.
Jetty	24,027
Timber wharfing	9,506
Sea channel	4,986
Entrance and gates . . .	17,720
Dock	56,761
Hydraulic machinery . . .	9,000

Possessing peculiar advantages over all the other tidal harbours

PLATE 11. VOL. XXI.


Fi
H
13.'0"
7.'0"
30.'0"
H
G
SIN.
G
Fig
ater
6"
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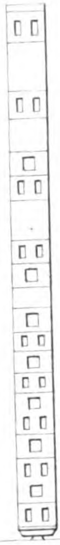
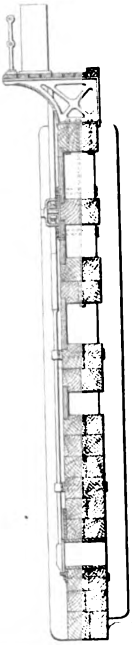
ste
7.
Fig:15.
35.'6"
26.'4"
30.'10"
ECTION C D.
TI
IN

Fig: 19.



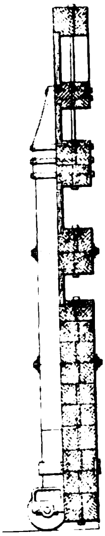
ELEVATION OF HEEL POST.

Fig: 20.



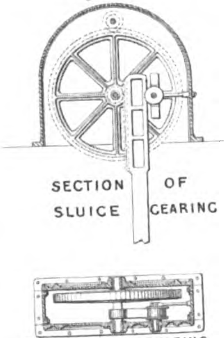
SECTION A B.

Fig: 21.



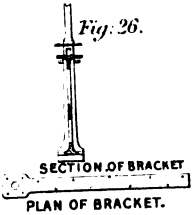
SECTION C D.

Fig: 25.


SECTION OF
SLUICE GEARING

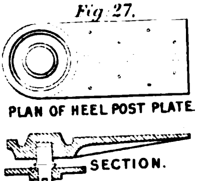
PLAN OF SLUICE GEARING.

Fig: 26.


SECTION OF BRACKET

PLAN OF BRACKET.

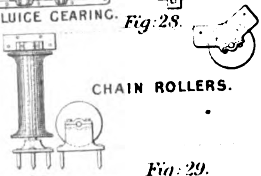
Fig: 27.



PLAN OF HEEL POST PLATE

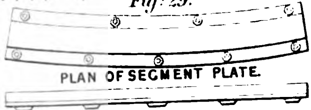
SECTION.

Fig: 28.



CHAIN ROLLERS.

Fig: 29.



PLAN OF SEGMENT PLATE.

ELEVATION.

KELL BROS LITHRS CASTLE ST HOLBORN.

OF THE
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OF
CAL

SWANSEA DOCKS

HYDRAULIC MACHINERY FOR SHIPPI

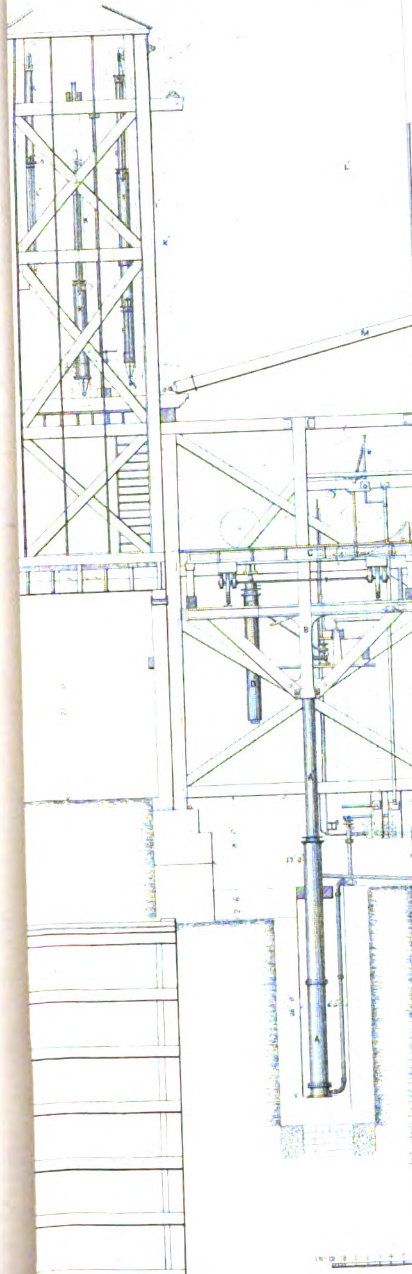
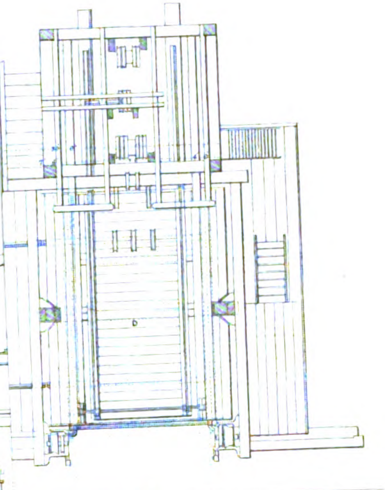

L
K
M
C
B
D
A
Scal

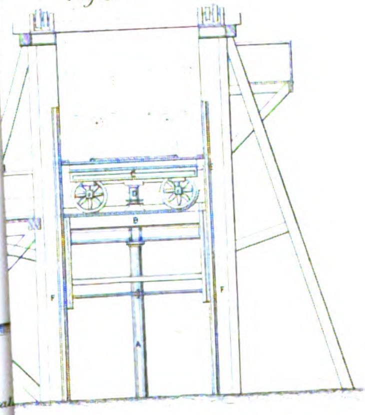
Fig. 5.


D
Edge of Quay

PLAN OF COAL HOIST

Shoot

Fig. 6.



ONT VIEW OF COAL HOIST

KELL BROS LITHRS CASTLE ST HOLBORN

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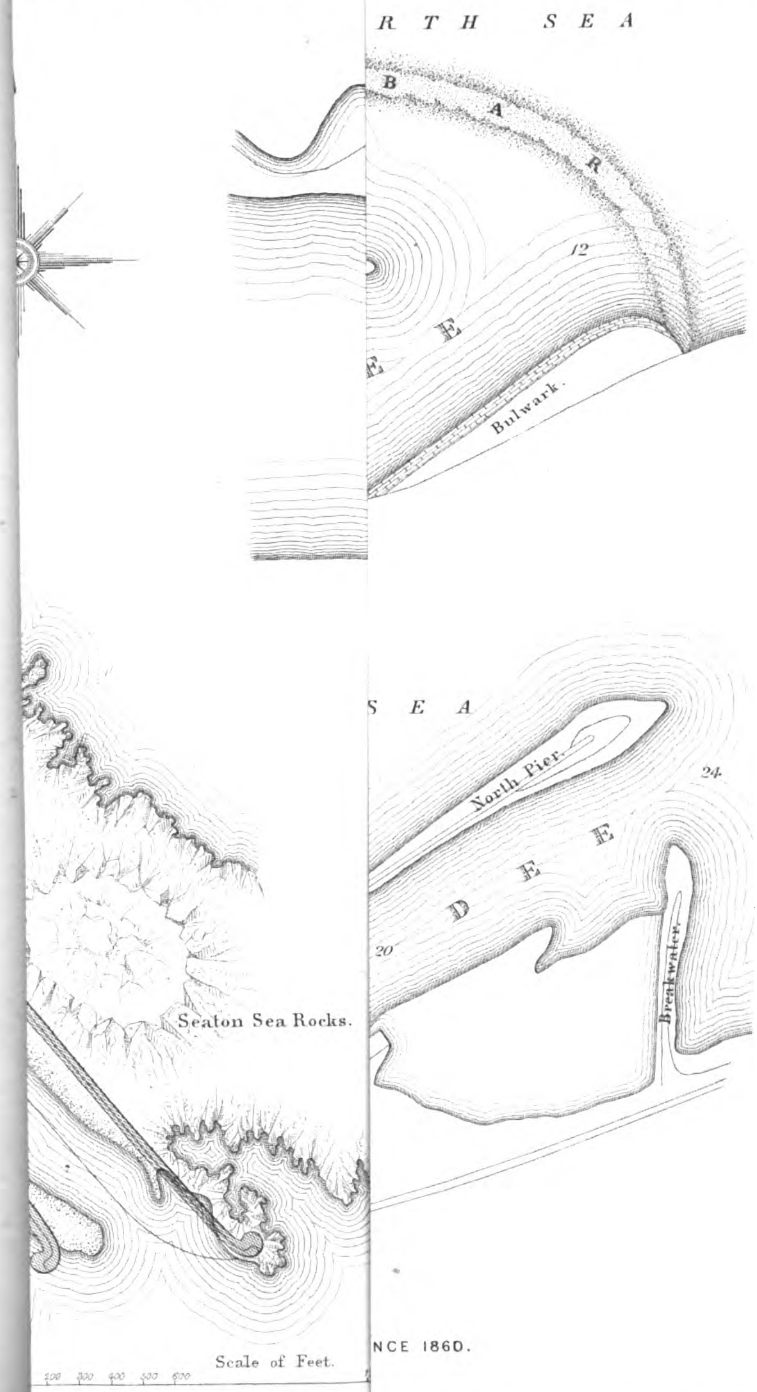
TH AND ABERDEEN


R T H S E A
B
A
R
12
E
E
Bulwark.
S E A
North Pier.
24
E
E
D
20
Breakwater.
Seaton Sea Rocks.
NCE 1860.
Scale of Feet.
200
300
400
500
600

KELL BROS LITHRS CASTLE ST HOLB

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SILLOTH DOC

PLATE 14. VOL: XXI.

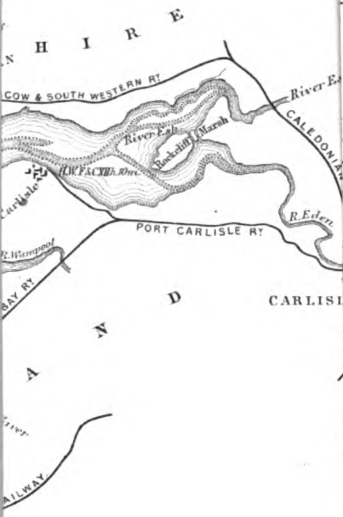
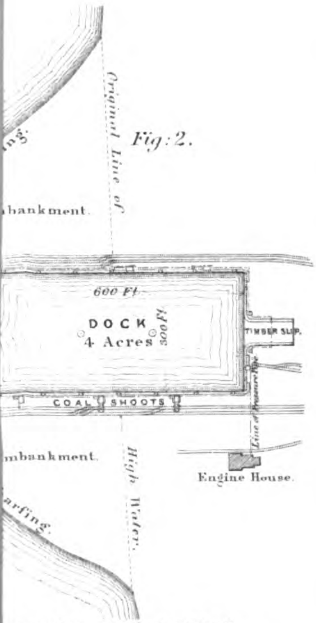
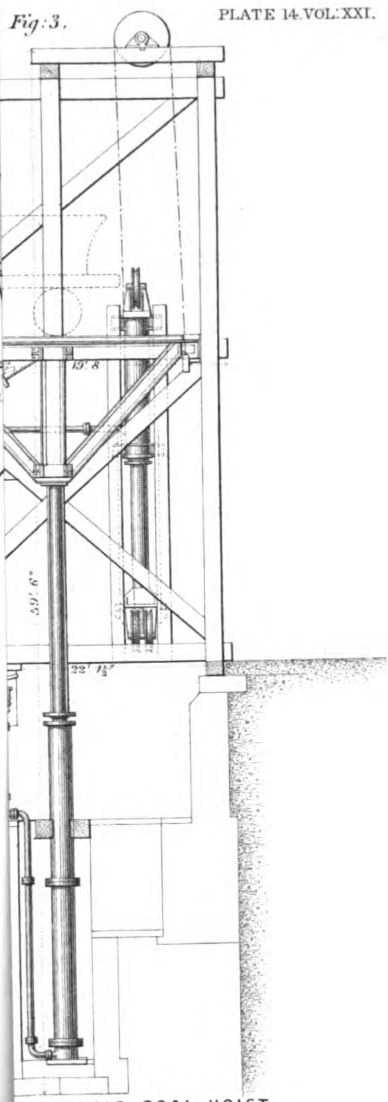

N H I R E
COW & SOUTH WESTERN RY
River Esk
CALEDONIAN
River Esk
Rockcliff Marsh
H.W. F.A.C. XIII h. 10m.
Carlisle
R. Eden
PORT CARLISLE RY
R. Wampool
BAY RY
CARLISI
D
N
A
River
RAILWAY

Fig: 2.


Original Line of
ng.
bankment.
600 Ft
DOCK
4 Acres
300 Ft
TIMBER SLIP.
COAL SHOOTS
Line of Pressure Pipe
mbankment.
Engine House.
High Water.
arfing.

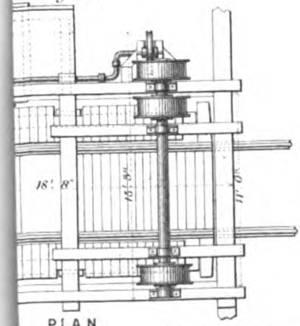
LARGED PLAN OF DOCK.

Fig: 3.


19'. 8"
39'. 6"
22' 1½"

HYDRAULIC COAL HOIST.

Fig: 4.



PLAN.

KELL BROS LITHRS CASTLE ST HOLBORN

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OF
CALIFORNIA

on the Cumberland coast, by affording an entrance to shipping at an early period of the tide, with a safe roadstead in its immediate vicinity, the Port of Silloth will undoubtedly rise to importance in connection with the gradually developing system of the Caledonian, the North British, and the Newcastle and Carlisle Railways.

The Paper is illustrated by a series of drawings and diagrams, from which Plates 11, 12, 13, and 14 have been compiled.

APPEN-

Table 3.—Swansea Harbour.

Steam Engines,

Description of Engine.	Steam Cylinders.				Feed Pumps.			Pressure.			
	Number.	Diameter.	Length of Stroke.	Maximum Number of revolutions per Minute	Number.	Diameter.	Length of Stroke.	Number.	Diameter.	Length of Stroke.	Maximum Number of Strokes per Minute.
		In.	Ft. In.			In.	Ft. In.		In.	Ft. In.	
80 H.P.	2	18	2·0	38	1	6	0·6	2	5¾	2·0	38
30 H.P.	2	14	1·6	60	1	4¾	0·4¼	2	3½	1·6	60
								Supply Pumps.			
12 H.P.	2	8&9	1·0	70	1	..	..	2	14	2·6	14

Hydraulic Machinery for Working

	Water Engines.					Capstans.		Gates.		Sluices.	
	Number.	Number of Cylinders to each Engine.	Diameter.	Length of Stroke.	Maximum Number of revolutions per Minute.	Number.	Maximum speed wound.	Number of revolutions of Engine to open, or shut one pair of Gates.	Time required to open, or shut one pair of Gates.	Number.	Number of Cylinders to each Sluice.
			In.	Ft. In.			Ft. per Min.		Min.		
South Docks.											
Lock	4	3	2⅝	1·2	45	4	45	100	2½	6	1
Single Entrance . .	4	3	2⅝	1·2	45	4	45	110	2¾	..	..
North Docks.											
Lock	2	3	3½	0·9	30	2	52½	55	2¼	..	..

DIX.

Details of Hydraulic Machinery.

Pumps and Boilers.

Pumps.				Cylindrical Boilers—Shell ⅜″ Plates, Ends and Flues ½″ Plates.							
Pressure of Water per square Inch.	Quantity of Pressure Water in one stroke of Pumps.	Maximum quantity of Pressure Water pumped per Minute	Maximum quantity of Pressure Water pumped per Hour.	Number.	Diameter of Shell.	Length.	Number of Flues per Boiler.	Diameter of Flue.	Number of Safety Valves per Boiler.	Diameter of Safety Valve.	Working Pressure per Square Inch.
Lbs.	Cub. Ft.	Cub. Ft.	Cub. Ft.		Ft. In.	Ft. In.		Ft. In.		In.	Lbs.
750	·7213	27·4	1644	3	5·6	21·0	1	3·1 tapering to 2·6	2	$3\frac{15}{16}$	55
750	·2004	12·02	721	2	5·0	21·0	1	3·0 tapering to 2·6	2	$3\frac{15}{16}$	55
..	..	..	..	..	..	..	..	..	..	..	..

Gates, Bridges, Capstans, and Sluices.

Sluices.			Bridge (Wrought-iron, one leaf).						Quantity of Pressure Water required.				
Diameter.	Length of Stroke.	Time required to open, or shut each Sluice.	Number of Cylinder.	Diameter.	Length of Stroke.	Diameter of Drum of Bridge.	Size of Chain.	Time required to open, or shut Bridge.	To open, or shut one pair of Gates.	To wind 900 Lineal Feet on Capstans (at the rate of 45 feet per Minute).	To wind 1,800 Lineal Feet on Capstans.	To open and shut four Sluices.	To open and shut the Bridge.
In.	Ft. In.	Min.		In.	Ft. In.	Ft. In.	In.	Min.	Cub. Ft.	Cub. Ft.	Cub. Ft.	Cub. Ft.	Cub. Ft.
5½	4·2	½	2	8½	5·6	14·0	1⅛	1½	53	..	238	5½	4½
..	..	..	..	..	..	..	..	..	58	119	..	..	..
			Swivel Bridge (two leaves).										
..	..	..	No. of revolutions of Engine required to open, or shut one leaf of Bridge. 45		..		..	1½	33	..	155	..	27

TABLE 4.—SWANSEA HARBOUR.

1¼ Ton Cranes

Number.			Lifting Cylinder to each Crane.					
North Docks.	South Docks.	Total.	Number.	Diameter.	Length of Stroke.	Size of Chain.	Power.	Maximum Lift.
				In.	Ft. In.	In.		Ft. In.
5	4	9	1	8¼	6 6	9/16	8 to 1	50 0

COAL DROPS,

Description of Drop.	Number of Drops.	DETAILS OF																	
		Lifting Cylinder for Waggon.				Tipping Cylinder for Waggon only			Traverser Cylinder.					Lifting Cylinder for Centre Chains.					
		Number.	Diameter.	Maximum Length of Stroke.	Average Length of Stroke.	Number.	Diameter.	Length of Stroke.	Number.	Diameter.	Length of Stroke.	Size of Chain.	Power.	Number.	Diameter.	Length of Stroke.	Size of Chain.	Power.
			In.	Ft. In.	Ft. In.		In.	Ft. In.		In.	Ft. In.	In.			In.	Ft. In.	In.	
*Coal drop for Boxes . .	1	1	13⅜	..	1 6	†	†	†	1	5⅜	4 0	½	4 to 1	1	9	9 0	¾	6 to 1
‡Coal drop for Waggons. .	2	1	13⅜	21 0	10 0	1	9	9 0	1	5⅜	4 0	½	4 to 1	..	..	§	..	..

* This drop is constructed to discharge coal from waggons as well as from boxes.
† Not required when shipping from boxes.

Details of Hydraulic Machinery—*continued.*

(Radius of Jib, 24 Feet).

Turning Cylinders to each Crane.					Quantity of Pressure Water used in One Lift of Crane complete.	Maximum No. of Lifts per Hour.	Remarks.
Number.	Diameter.	Length of Stroke.	Size of Chain.	Power.			
	In.	Ft. In.	In.		Cubic ft.		
2	4⅞	4 0	¾	2 to 1	3½	30	In discharging Ballast or Ore, the tub used weighs about 5 cwt.

South Docks.

One Drop.

Lifting Cylinder for Side Chains.					Jib Cylinder.					Quantity of Pressure Water used to lift and discharge Four Boxes of Coal or One Waggon.	Maximum Number of Boxes discharged per Hour.	Maximum Number of Waggons discharged per Hour.	Remarks..
Number.	Diameter.	Length of Stroke.	Size of Chain.	Power.	Number.	Diameter.	Length of Stroke.	Size of Chain.	Power.				
	In.	Ft. In.	In.			In.	Ft. In.	In.		Cubic ft.			
1	7	8 6	11/16	6 to 1	1	7⅞	4 6	11/16	4 to 1	20	36	..	There are four boxes to each waggon, and each box contains 2½ tons of coal.
..	..	..	..	..	..	..	..	..	..	15	..	12	The waggons contain from 10 tons to 12 tons of coal each.

---

‡ There are four hydraulic coal-drops in the North Dock for discharging from boxes, the hydraulic power for which is supplied by the South Wales Railway Company.

§ 1 foot 6 inches only of stroke requires pressure water.

TABLE 5.—SWANSEA HARBOUR.

STATEMENT, showing the Expense of Working the 80 H.P. Duplicate Steam Engine, and 12 H.P. Duplicate Steam Engine (for Pumping), in connection with the Hydraulic Machinery, for One Year, viz., from 1st November, 1859, to 31st October, 1860.

—	Coal.						Stores (Oil, Tallow, Waste Yarn, &c.)			Wages.			Repairs.			Total.		
	Steam Coal.	Bituminous.	Total.	Amount.														
1859	Tons.	Tons	Tons.	£.	s.	d.	£.	s.	d	£.	s.	d.	£.	s.	d.	£.	s.	d.
November	81	4	85	31	14	6	11	14	2	18	12	0	5	8	7	67	9	3
December	143	9	152	56	13	3	4	12	6	24	19	6	20	18	10	107	4	1
1860																		
January	90	4	94	35	2	0	5	10	10	19	8	0	27	3	8	87	4	6
February	120	13	133	49	7	9	6	5	7	24	7	1	31	9	4	111	9	9
March	72	25	97	35	8	9	6	2	6	18	18	6	21	5	10	81	15	7
April	120	20	140	51	15	0	4	14	8	20	11	8	5	10	5	82	11	9
May	138	22	160	59	3	6	7	7	3	27	19	0	12	8	3	106	18	0
June	120	22	142	52	8	6	6	11	1	20	14	5	18	9	11	98	3	11
July	138	23	161	59	10	3	9	6	7	21	13	3	14	19	4	105	9	5
August	120	22	142	52	8	6	6	1	0	29	1	5	18	2	3	105	13	2
September	156	23	179	66	5	3	5	14	0	21	9	3	10	18	6	104	7	0
October	130	30	160	58	17	6	8	0	9	22	15	9	10	6	3	100	0	3
Gas	..	..	..		..			..			..			..		18	15	0
Total	1,428	217	1,645	608	14	9	82	0	11	270	9	10	197	1	2	1,177	1	8

Average Expense per Week £.22 12 8 say £.22 16 1

Mr. J. MURRAY said he had specially studied the peculiarities of the harbour of Aberdeen. The coast, for about 14 miles to the northward of the River Dee, was low; it was composed of sand drifted about by north and north-east winds, and formed a series of dunes, or sand-hills. The southern, or right bank, terminated in a bold headland, called the Girdle Ness, which jutted out for some distance beyond the general line of the shore. The set of the flood tide along the coast was to the southward, and it carried the detritus within its influence to the mouth of the Dee, where it was arrested by the Girdle Ness. Thus the estuary which formerly existed to the northward of that headland had gradually filled up. A sand-spit had accumulated on its north side which had progressively increased in length and width, dunes had been formed upon it, and the fore-shore which had thus grown up was now called the Links. The former bay within the sand-spit gradually silted up, and after it was reclaimed the lower portion of the town of Aberdeen was built upon it. Subsequently, by successive accretions, the inner estuary, with the exception of a few unimportant channels, had also become dry land, and these channels were polluted with the sewage of the town, and were only cleansed from the filth which accumulated in them when occasional great floods came down the river. From the previous condition of the river and the estuary it was to be inferred that the outlet was formerly in a northerly direction, and that it had a bar across it; but that, in consequence of the progressive increase of the spit of sand, the direction of the outlet had been changed to the eastward, and that the continuation of the spit under water had formed the bar. Mr. Smeaton being called in to provide a remedy for the shallow depth of water on the bar, which was then a frequent occurrence, described the case with his usual ability and minuteness. He noticed, that the set of the flood, with on-shore gales, carried the detritus to the southward, and raised the bar occasionally 2 feet, or 3 feet in height; and in consequence he recommended the erection of a pier on the north side of the entrance, which, he said, would not only keep the freshes confined in a body, until they came into deeper water, but would also prevent the sand and gravel from being driven into the mouth of the river. Mr. Smeaton appeared to have considered, that when the pier was erected, the action of the freshes, during spring tides, would prevent the bar from attaining the height which it had previously acquired, as the matter which, under the former state of circumstances, had been deposited upon it, would, when the north pier was erected, have a tendency to be carried round the headland of Girdle Ness. He also recommended that the larger stones which encumbered the mouth of the river should be lifted, in order that the remaining gravel might be swept out to sea by the scour of the ebb.

The absence of a bar at the present time, at the harbour of Aberdeen, was attributable, not so much to the influence of tidal water, as to the effect of the freshes, which came down the Dee with great impetuosity from a catchment basin of about 900 square miles of country, surrounded by high hills, one of which, Ben MacDhuie, had an elevation of 3,550 feet above the level of the sea. The river thus frequently became the channel for a large volume of water, which rose very suddenly. At the site of the suspension bridge, about 2 miles from the pier heads, there was a natural stricture, as the river at that point was only about 200 feet wide. He had been informed that at the suspension bridge, the water during floods, sometimes rose 10 feet, and often 7 feet, above the level of the high water at the sea. Below the bridge the river expanded, and a large portion of the water passed down the Spillwater, where the width of the river was about 650 feet. Between the piers at the entrance, the width was about 300 feet. If it was assumed that a great flood would raise the water surface there, 2 feet above the level of the sea, the velocity of the out-going current would be such as wholly to preclude the salt water from entering the river. He had calculated that the velocity of such a flood would be 8 knots, or 9 knots per hour. A velocity of from 4 knots to 5 knots per hour was no uncommon occurrence. Interior works had been executed under the direction of Mr. Telford, to prevent the current from running through the part of the harbour which was now converted into a wet dock. The late Mr. Robert Stevenson, of Edinburgh, had ascertained that there was a considerable set of tidal water running into the harbour, as an undercurrent, at times when there was a strong current of fresh water at the surface running out over the top of the tidal water. Mr. Murray would only passingly allude to this, as he had already drawn attention to it in his Paper on the North Sea.[1] The proposal for the conversion of the harbour into a dock, since carried into execution by Mr. Abernethy, had raised the question as to the effect which would be produced upon the mouth of the river by the abstraction from its tidal surface of an area of 34 acres. The Admiralty officers had calculated that 500,000 cubic yards of water would be excluded from the river at each tide by the formation of the dock, and that the diversion of the river with an embankment of 30 acres of ground, the greater part of which was covered at high tides, would exclude as much more. In consequence, they advised great caution in the execution of the works. The Admiralty survey, made since their completion, however, showed no diminution of depth on the bar. It was therefore obvious that the depth of the channel and upon the bar was not so much dependent upon the effect of the tidal water, as upon the scouring action of the freshes.

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[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xx., p. 325.

He would inquire how it was that so large a sum had been expended in the construction of the dock at Silloth? No doubt the formation of a small dock, of 4 acres in extent, would be more costly than one of from 10 acres to 20 acres. By the Paper it appeared that the total cost of the dock at Silloth was £57,000, which showed that an expenditure of £14,250 per acre had been incurred in its construction.

Mr. DAVID STEVENSON said, that his father, Mr. Robert Stevenson, made the observations on the currents of the River Dee at Aberdeen alluded to by Mr. Murray, when surveying the river in the year 1810. It was then clearly ascertained, that on certain occasions there was a perceptible outward current at the surface during the whole period of the flood tide, and that simultaneously there was a current of sea water running inwards. The salt water flowed in underneath, raising up the fresh water, the fresh water in reality running out over the top of the salt water. These results were perhaps due to the steepness of the Dee and the velocity with which the fresh water ran down that river; and they tended to show, that the harbour of Aberdeen was not solely kept open by the influence of the fresh water, or the river floods, inasmuch as the fresh water was obviously inoperative on the bottom while it was running out over the salt water. The assertion, that the Dee was a river without a bar at its entrance, must arise from some misapprehension of the facts of the case, as he understood that it had a very distinct bar, the depth upon which was constantly varying.

Mr. A. GILES, had been engaged with the late Mr. Rendel, in opposing the passing of the Act which authorised the formation of the Silloth Docks; but he had not been at Silloth since the works were in progress. At the period of his examination, he thought the locality to be very unpromising. Although there was tolerably deep water in Silloth Bay, the shore itself was a drifting sand, and the entrance of the dock was liable to be silted up by every gale. If the channel excavated by dredging, and protected by the pier, had been kept open for two years, under those disadvantageous circumstances, a great engineering success had been achieved. He had seen the Swansea Docks two, or three years ago. Looking at the cost of constructing the hydraulic machinery, he was at a loss to discover the great advantage of its application to the opening and shutting of the lock-gates. By the Paper it appeared that the gates at Swansea were 56 feet wide, and that they could be opened in three minutes. In his judgment the same rapidity could have been attained by ordinary means. The expense of the hydraulic apparatus at Silloth was stated to be £9,000, and the cost for maintenance and labour would therefore be about £900 a year. This expenditure was very heavy, if it was incurred solely for opening and shutting the lock-gates. Even with hydraulic machinery, a man was required on each side of the lock-gates, and gates 56 feet wide could be opened by manual labour alone, with two men on each side. He was ready to admit that, when hydraulic machinery was applied to the general work of a dock, it was extremely useful; but, taking the case of the Swansea docks, where the hydraulic apparatus was applied to the gates only, he thought that the slight saving of time, scarcely justified the great additional expense.

Mr. T. E. Harrison said, that it was an error to suppose that an amount of £9,000 had been expended solely on the hydraulic apparatus for the dock-gates at Silloth. He had personally examined the docks, and he found that the hydraulic apparatus was applied to the lifting of the waggons, and the working of the cranes. His own experience had convinced him that hydraulic machinery, if used for the other purposes of a dock, could be applied with great advantage and economy to the opening and shutting of the lock-gates. With reference to what had been stated in regard to the existence of an upper and lower current on certain occasions in the Dee, he considered it possible that similar counter-currents might exist in other rivers, where as yet they had not been observed. When the last of the ebb was running down a river, it was a common occurrence to find the young flood tide creeping up in shore. No doubt the flood tide to a certain extent counteracted the action of the downward stream of a river. It must, however, be remembered that during the whole of the ebb tide there was not only the ordinary effect of the ebb stream, but, in addition, that of the land water. Great effects were produced upon all rivers by the floods and freshes. He had seen cases in which a river had been deepened 10 feet in twenty-four hours by heavy floods; and in the case of the Dee he had no doubt that when the freshes were heavy, they exerted a great effect in maintaining the depth of water over the bar.

Sir William Armstrong observed, that as his connection with the application of hydraulic machinery was only in the character of an Engineer, he did not feel himself responsible for the commercial part of the question. It was the duty of those who were concerned in the profits of the works to judge of the expediency of applying that machinery, and it was the duty of the Engineer to apply it in the most economical and efficient manner. The cost of the hydraulic apparatus for the dock-gates was not, however, so large as had been stated. So far as regarded the gates alone, its cost would not be more than about £900, exclusive of the chains, rollers, and crabs, which adjuncts would be required whether manual power, or water power was used. There could be no doubt that where hydraulic power was required for the other purposes of a dock, it was an advantage to apply it to the gates. The hydraulic apparatus gave perfect command over the speed, so that three minutes might not be taken as its limit; but the lock-gates might be opened, or closed, as rapidly, or as slowly, as was thought desirable.

As to the machinery for shipping the coal, he would remark, that in Wales the coal was very friable, and the great consideration was to load it with as little breakage as possible. Another point had to be attended to at Swansea. The waggons in that part of the country were formed to discharge by tipping, and not by dropping their contents from the bottom of the waggon. The latter process was the more simple of the two. When waggons of great weight were used for tipping coal, it was necessary to have hydraulic power to perform that operation with facility. The ships frequenting the port were also of large size, and the levels, at which the loading was effected, were very various. Sometimes a ship would be so high out of the water, that the height of the loading-stage became insufficient, without the application of lifting, as well as lowering, machinery. The coal was also conveyed to the vessels sometimes in boxes, and sometimes in waggons; but, notwithstanding the complicated conditions involved, the hydraulic machinery seemed fully to answer the various purposes for which it had been designed.

Admiral Sir **Edward Belcher** said, that his attention was drawn to the site of the Swansea docks in 1848, when he was requested by the late Sir Francis Beaufort, then hydrographer to the Admiralty, to effect an adjustment of the conflicting opinions held by the inhabitants, as to the merits of the various proposals of the different Engineers who had been consulted on the subject. The inhabitants eventually agreed to submit the whole matter to Sir F. Beaufort, who recommended the construction of the docks which had been described in the Paper. Sir E. Belcher had visited the locality since the docks had been completed, and he could bear testimony to the great, he might say wonderful, improvement which had been effected in the port by their construction.

In reference to the separate streams which occurred in the estuaries of most rivers during the interval of the flood tide, he would cite an instance as regarded the River Thames. At Woolwich the river water was fresh at the first quarter of the flood; and in 1824, and 1825, the ships of war, fitting at Woolwich, were supplied with fresh water from the Thames, pumped up from alongside at the turn of the tide, and up to the first quarter of the flood; but the end of the pump, or hose, was never allowed to be more than 2 feet below the surface of the river. If that precaution was neglected, and the hose was inserted 3 feet below the surface, salt water was immediately pumped up. This clearly showed that at Woolwich the salt water flowed up underneath the fresh water. In the case of the River Dee, he considered that the salt water exercised a beneficial action on the general regime of the river. The specific gravity of the salt water was greater than that of the fresh, and in consequence, the young flood tide acting as a wedge, forced up the lighter matter of the silt, which, when disturbed, floated on the surface of the fresh water, and was carried over the flood tide towards the sea. The velocities of streams and currents were usually exaggerated. He had on numerous occasions tested the velocity of streams which had been alleged to run at the rate of 7 knots, or 8 knots per hour. In one of those cases, that of the River Douro, he found it amounted only to 3·6 knots, or 3·75 knots per hour; in the case of the Tagus, to only 3·6 knots per hour; in that of the entrance to San Francisco, California, it was 4 knots per hour. The greatest velocity of current he had met with was off Alderney, where it was actually running 8 knots per hour, but that was a race. He had tested the velocity of the current at the falls of Niagara, from the centre of the bridge between the American shore and Goat Island; and, notwithstanding the great inclination of the surface of the water, he found that the velocity only amounted to 12 knots per hour.

Mr. D. STEVENSON could not agree in the proposition that the phenomena of the currents of all rivers, at flood tide, were similar to those which had been observed in the Dee, at Aberdeen. In the case of the Cromarty Frith, Mr. Alan Stevenson found the undercurrents at the depth of 50 feet to be, both on the ebb and the flood, nearly double the velocity of the surface currents; but the directions of the upper and lower streams were not opposed to each other. As regarded the effect of the fresh water upon the channel of the River Dee, he considered that wherever the physical circumstances of a river were such, that there was very little, and at certain periods, no indraught during flood tide, the fresh water which ran out on the surface could not be held to be so effective, as it would be in what might be termed the normal, or ordinary condition of tidal rivers, where the tide produced a strong inflowing current, and the salt and fresh water united in a still stronger outflowing current, and thereby occasioned a regular scour on the bottom both by the inward and the outward streams. Without this double action, the fresh water, as in the case of the Dee, was in a great measure rendered inoperative.

Mr. COCKBURN CURTIS remarked, that longitudinal and cross sections of the River Dee would be a valuable adjunct to the Paper, as they would probably at once show the cause of the phenomena to which reference had been made. Similar anomalies had fallen under his notice, in rivers which he had examined, or had reported upon; but he had always found, that they had their origin in some peculiarity in the configuration of the shores, the cross section, or the slope of the river. As a general rule, inexperienced persons were apt greatly to overrate the velocity of streams, or currents.

Mr. J. MURRAY said that the information he had received on the subject of the velocity of the water in Aberdeen harbour was, that at the suspension bridge, 2 miles from the bar, a great flood rose 10 feet above the high-water level; whereas, between the piers, during the ebb tide, the surface of the water was not more than 5 feet above the low-water level. With a given length and fall it was, therefore, easy to calculate the velocity, and he had done so, and found it to be between 7 knots and 8 knots per hour. As regarded the velocity of currents, he would call attention to the rapidity of the streams in the Pentland Frith, which had been ascertained by Capt. Otter, R.N., in the course of the Admiralty survey, to be from 8 knots, to 9 knots per hour.

Mr. JAMES LESLIE considered it a mistake to lay down any general rule, as to the comparative effect of fresh water and tidal scour, inasmuch as it depended upon the relative size of the river and its estuary. When the estuary was small, the scour resulted almost entirely from the river water; but when the estuary was large, and the amount of fresh water small, the effect of the tidal water would be greater than that of the fresh. For instance, in the Tay, near the mouth, the tidal water had about a hundred times the effect of the fresh water. Higher up the effect became proportionally less, until at a point a little below Perth, the scour was almost entirely due to the fresh water coming down the river.

Sir JOHN RENNIE, Past-President, had surveyed Blyth harbour about forty years ago, for his father, the late Mr. Rennie, who proposed plans for its improvement, somewhat similar to those which had now been carried out. As Sir J. Rennie had already expressed his opinion as to the inexpediency of putting the stones in wooden frames, it would be unnecessary that he should again detail his objections to that mode of construction. As regarded the question of tidal and fresh water scour, he would draw attention to the fact, that when the tidal water greatly preponderated, a harbour partook of the character of a lagoon. The maintenance of the depth of water in a lagoon depended chiefly upon the state of the water which came into it. If the water held large quantities of alluvial matter in suspension, then the probability of extensive deposits was very great, and in the absence of fresh water to clear them out, the lagoon in course of time would be filled up.

Mr. ROBERT RAWLINSON considered the proposed canalization of the Tawe to have been a great mistake. In this climate the volume of water in rivers was frequently greater in flood than in dry seasons, the ratio increasing from 1 to 100 to 1 to 300, or more. Rivers, under such conditions, could not be kept economically under control by artificial means. Mr. Brindley was stated to have said, that he considered rivers useful only, as feeders to canals. Some rivers in Great Britain rose, during floods, 20 feet above their dry-weather level. The Eden at Carlisle; the Mersey, and the Medlock, near Manchester, were instances. At such times their waters were loaded with silt, which would soon block up any river converted into a dock. In reference to the reputed under-current in the Dee at Aberdeen, he did not consider such a current could exist as a true current, or that a continuous current could be running up a river with another continuous current running over it in the opposite direction. There might apparently be an up-current motion in the water beneath the surface, but he contended that in reality it was only an under roll, or eddy, caused by the rapid downward motion of the flood water in the river. In rivers and seas there might be bottom eddies, in the same manner that there were side eddies. In straits such as those of Gibraltar, and of the Bosphorus, there might be both distinct surface, and under currents, in, and out. In rivers having a gradient this could not be the case. As regarded the velocity attained by streams and currents, he had particularly noticed the great rapidity of the stream in the Mersey, at half tide of spring tides. In some parts of the mid-channel of that river it ran at the rate of 7 knots an hour, a powerful steamer being scarcely able to stem it.

Mr. ABERNETHY, in reply, said, an idea appeared to be entertained that the harbour of Aberdeen was dependent for the nonexistence of a bar, not so much upon the tidal water as upon the freshes which came down the River Dee. That opinion, so far as it regarded its present state, was erroneous. The space of land to the north of the Dee was formerly a portion of an extensive tidal estuary. Of this there were abundant proofs; amongst others, the remains of old vessels, anchors, &c., had been discovered when excavating the sites of the docks. Uprooted trees were also found amidst the debris which had been brought down by the floods. At that period, probably, the land floods had some influence in preserving the entrance to the channel; but since then the character of the river had been entirely changed. In 1661, as was shown by an authentic plan of that date, the land waters had not sufficient force to remove the bar which then existed beyond Sandness point. In 1841, when the docks were first projected, it was argued, that the abstraction of the required tidal area would injure the entrance to the harbour, unless compensation was made for it by dredging the channel; and such was also his own view of the case. In consequence, extensive dredging operations were carried out, previously to the commencement of the docks, and during the period of their construction. The dredging had also, to a certain extent, been continued up to the present time, the result being, that the volume of the tidal water now greatly preponderated over that of the fresh; and the sea water, which held no matter in suspension, added to the fresh waters of the Dee, had produced such an out-going current as to remove the bar. No bar had existed since the year 1841 that he had been able to detect; therefore the assistance of the river floods were no longer required to remove it. In fact, the river floods were to some extent detrimental, inasmuch as they brought down debris, which lodged in the bend leading up to the dock, and in other portions of the harbour, where eddies existed, or where the current had not sufficient force to carry it along towards the sea.

As regarded the cost of the dock at Silloth, he would explain that it was formed on a part of the sea-shore where there were lofty sand-hills, and in constructing the docks it was necessary to clear away a space of 30 acres round their margin, for railway and other purposes; hence, a great portion of the expense was incurred for the excavation. At the same time he was not prepared to admit that £14,250 per acre of dock area was an excessive outlay, or beyond the average cost of the docks which had heretofore been constructed in England.

It had been stated that no general rules could be laid down for the treatment of rivers; but he apprehended that Engineers would eventually arrive at some rules, or data, as to the separate treatment to be adopted in the case of two classes, namely, that of tidal rivers, and that of those rivers dependent upon the volume of fresh water which they delivered to the sea. Of the latter class he would cite, as examples, the Mississippi, the Danube, and the Nile. In such rivers, although parallel walls might be constructed to project the current through the delta which formed at their outfalls, so as to produce for a time an improved channel, still the debris brought down by the river waters would again prolong the delta, and necessitate the projection of the works *ad infinitum*. He considered that the best way of providing an entrance channel for such rivers, was to select a site on the coast at some distance from the mouth, where the tidal and other features were the most favourable, to cut a canal from that point to the river, and to effect the entrance into the river by means of a lock, or locks.

It was a mistake to suppose that the cost of the machinery as applied to the lock-gates at Silloth was £9,000, as on the contrary it was not more than £700 for each pair of gates, or £350 for each leaf, the interest of which sum was less than the annual wages of one man. The trade of the present day could not be carried on in some docks without the aid of hydraulic machinery. He had recently been consulted upon the subject of affording greater accommodation for the trade of Aberdeen. The idea had been entertained of enlarging the docks at that port, which at present had an area of 34 acres; but he pointed out that with the application of hydraulic machinery, five times the present amount of business could be carried on; and that, in consequence, no enlargement of the docks would be necessary. He considered that dock Engineers were greatly indebted to Sir William Armstrong for an apparatus which could be so readily applied to the general purposes of dock operations.

Mr. HAWKSHAW—President—said, that the Paper was peculiarly valuable, as it gave an account of several important works which had been successfully carried out by the Author, and it was accompanied by elaborate and carefully-executed drawings. The question which had been raised of the relative effects of upland floods, and of tidal water, upon the bars of rivers, was one which was too important to be discussed in a merely incidental manner. He hoped that the Institution would be favoured with a paper specifically treating upon that subject.

March 25, 1862.

JOHN HAWKSHAW, President,
in the Chair.

The discussion upon the Paper, No. 1,052 "Description of Locks at the Ports of Swansea, Blyth, and Silloth," by Mr. ABERNETHY, was continued throughout the evening to the exclusion of any other subject.

April 1, 1862.

JOHN HAWKSHAW, President, in the Chair.

The following Candidates were balloted for and duly elected:—WILLIAM HENDERSON, WILLIAM HENRY MILLS, ALEXANDER SAMUELSON, CHARLES INNES SPENCER, MARRIOTT OGLE TARBOTTON, and THOMAS WARING, as Members; CHARLES COLES ADLEY, RICHARD GEORGE COKE, WILLIAM DUNLOP, GEORGE POWNALL, and SAMUEL LEITH TOMKINS, as Associates.

No. 1,059.—"Railway Accidents—their Causes and Means of Prevention."[1] By JAMES BRUNLEES, M. Inst. C.E.

As the Author considers, that the causes of railway accidents are, in nearly all cases, sufficiently apparent, he will not attempt by theory to establish rules for their prevention, but proposes to treat the subject by dealing with the facts as they are; and as the whole of the details bearing upon this important question, cannot be comprised within the necessary limits of a single Paper, he intends to confine himself to indicating the principal causes of these alarming and expensive occurrences, and incidentally to offer such suggestions for their avoidance, as have occurred to him during his professional practice; believing that by adopting such a course, sufficient will be found in the Paper to lead to a full discussion, as to the best practical mode, of endeavouring to lessen the loss of life and property which they occasion.

The tabular statement on page 346, which is compiled from the Reports of the officers of the Board of Trade, shows, that during the seven years from 1854 to 1860, inclusive, the number of accidents amounted to 540, as the result of 1,274 distinct causes. Of these accidents, 11 per cent. were attributed to the permanent way, 7 per cent. to the rolling stock, and 76 per cent. to mismanagement, "including insufficient means for securing safety," leaving only 6 per cent. as not ascertained. The Author proposes to use these

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[1] The discussion on this Paper, in conjunction with the succeeding one on the same subject, by Captain Galton, was continued over portions of four evenings, but an abstract of the whole is given consecutively.

TABULAR STATEMENT, showing the CAUSES of the RAILWAY ACCIDENTS which occurred in Great Britain and Ireland during the Seven Years, from 1854 to 1860 inclusive.

Classification adopted.	1854	1855	1856	1857	1858	1859	1860	Totals.	Totals.	Per Cent.
PERMANENT WAY.										
Defective construction	9	24	22	15	24	11	13	118		
Neglect	4	7	..	5	5	3	1	25	143	11 per cent.
ROLLING STOCK.										
Defective construction	3	12	10	7	10	8	13	63		
Neglect	3	6	..	7	5	5	1	27	90	7 per cent.
MANAGEMENT.										
Insufficient accommodation	14	9	5	6	10	8	6	58		
Insufficient establishment	13	16	9	4	12	6	1	61		
Want of engine power	6	6	..	2	3	..	..	17		
Want of breaks	2	5	7	10	19	12	10	65		
Want of communication between guard and driver	8	9	1	7	3	1	2	31		
Want of adequate signals	16	17	15	9	5	12	14	88		
Want of time-pieces	5	6	4	..	..	..	..	15		
Want of turn-tables	..	..	..	..	2	..	..	2		
Unpunctuality	14	15	5	4	5	5	2	50		
Insufficient, or badly enforced regulations	41	41	27	25	36	12	16	198		
Insufficient interval between the trains	15	15	9	13	12	3	3	70		
Negligence of servants	36	36	27	35	28	17	32	211		
Speed too great for class of road	..	..	..	..	2	3	3	8		
Want of electric telegraph	24	22	10	17	14	7	3	97	971	76 per cent.
Causes not ascertained	21	22	7	16	2	1	1	70	70	6 per cent.

data as the basis upon which to found his remarks, and to adopt the same order of classification. Under the term permanent way, he includes all that belongs to its construction and maintenance, and in like manner under that of rolling stock, all that appertains to the engines and carriages running on the rails.

PERMANENT WAY.—As regards accidents arising from a defective state of the permanent way, it will be generally admitted, that on all the main lines of railway, as well as on many of the secondary lines, there is no lack of materials which, if properly applied, would make a good, safe, and efficient road; but when passing over these lines at high speed, it becomes apparent that many of them are in such a defective state, as to preclude the economic working of the traffic and to hazard its safety. The defects most evident are in the system of ballasting, of joint-fishing, of turning the rails, and of fastening the chairs to the sleepers. Good ballast is to a railway what a good foundation is to a building, and it would be well if more attention was bestowed upon its selection. The ballast in ordinary use too often consists of a bottom layer of inferior material, covered over with a top-dressing of sand, or gravel. It may be argued, that in many cases the cost of a better material would not warrant its employment; but experience shows, that it would be economical to have at least 6 inches, or 9 inches of rough gravel, or broken stone, as a free draining bed to the sleepers and to the 'top-dressing.' Engineers are well aware that subsidence and lateral deviation are often due to bad ballast; and that almost all the oscillating, rolling, or plunging motions of locomotives, arise from the same cause. A well-ballasted and well-drained road, will render the sleepers and rails far more durable, will lessen the cost of maintenance of the way and of the rolling stock, and above all, will tend greatly to prevent accidents.

Most railway accidents occur during the winter, and in this changeable and uncertain climate, that is not surprising. It frequently happens, that the early winter months are so wet as to render any attempt to repair the roads worse than useless. Frost then sets in, and the road remains in a bad state for weeks, if not for months, and as a necessary consequence, it is in its worse condition, when the tyres and axles are most brittle and least able to encounter its inequalities. As this untoward state of affairs tends greatly to augment the number of accidents, it is evident, that during the months of September and October, an extra number of men should be employed to drain the ballast and beat up the road, in order that it might become consolidated, before the winter's rains and frost set in. The pernicious effects of frost on wet ballast would thus be avoided, and although additional labour and outlay would for a time be required, it must be remembered, that fewer repairs would be afterwards needed, and that throughout the winter, a good and safe road would be secured. Many of the accidents have been caused by bad joints. These are also a great source of wear and tear to the rolling stock and of discomfort to travellers. The plan now in general use, of placing the fish-joint between two sleepers, is objectionable, as the ends of the rails are unsupported except by the fish plates, which when taken together, frequently have a section only equal to two-thirds of the section of the rail. It must be obvious, that if the fishes are strong enough to carry the load by themselves, the extra section of the rail is unnecessary; and, in fact, a rail weighing 54 lbs. to the yard, when properly fished, is equal in strength to a rail weighing 80 lbs. to the yard, supported by fishes which together have only two-thirds of the sectional area of the rail. It is true that the engines and carriages run smoothly upon rails which have been fished on the present system, for a short time after they are first laid down, but the rails soon become harsher and more unpleasant to ride over than those without fishes. The weight and momentum of each passing engine and carriage occasions a heavy blow at the joint, which strains and wears away the bolts, and gradually allows more play to the ends of the rails, until they are eventually bent down. The results of the Author's experience induce him to recommend, that all the joints should be fished directly over a sleeper, or that a bracket chair should be used. On one line of railway, 20 miles in length, on which there is a constant and heavy mineral traffic, he has used Mr. Samuel's bracket chairs, and after a wear and tear of nearly five years, the joints are as good as when the rails were first laid. The heavy engines and trains in common use, and the high speeds at which they are run, afford additional reasons for the adoption of a better system of joining the ends of the rails, while it is further evident, that in proportion as the road is made, and kept, firm and smooth, and the wheels of the rolling stock are in good order and well balanced, higher speeds can be obtained without increasing the danger, or the injury to the permanent way.

Accidents also arise from the practice of turning the rails. A rail should be considered and treated as a girder, the duties of which it has on a small scale to perform. When it is so much worn as to require turning, its strength is generally so reduced as to render it unfit for main-line traffic, and it should at once be taken up and re-rolled, or at any rate should only be employed in a siding. A new rail is cheaper and safer for the main line. So convinced is the Author of the danger which is incurred by this practice, that he is now using a rail which cannot be turned, as it has only one table for the wheels to run upon. With regard to the fastenings of the chairs to the sleepers, it is desirable, that iron spikes only should be employed on the outer side of the curves, or else, that the chair should be partially sunk into the sleeper, to lessen the strain on the treenail. When a train has left the rails on a curve, it has frequently been found that the accident has arisen from the failure of the treenails. To remedy the difficulty, a chair has been devised in which a projection on the sole, fits into a corresponding recess in the sleeper, and thereby prevents any strain coming on the spike, or treenail.

The Author must also incidentally notice the superior economy of steeled, or partially steeled, rails, points, and crossings. These are daily coming into use. They are about £1 per ton more expensive in first cost than ordinary rails; but if their durability is taken as only double, there can be no doubt of the advantage gained by their use. They also render the roads mechanically safer.

In the year 1854, thirteen accidents occurred from the defective condition or neglect of the permanent way. One on the London and North-Western Railway, near Huddersfield, was occasioned by a joint key slipping out, and another on a curve on the Great Northern Railway, was attributed to the use of wooden treenails, instead of iron spikes, for fastening the chairs to the sleepers. In the year 1855, thirty-one accidents arose from the same causes. One of these, occurred on the Wimbledon and Croydon Railway, owing to the road having been constructed without sufficient ballast. Another, on the London and North-Western Railway at Preston Brook, from the permanent way being too light for the traffic. The next, on the North British Railway, was attributed to a joint key having fallen out, the permanent way being in a generally defective condition; and another, on the South-Eastern Railway, in the Higham Tunnel, was also owing to the defective condition of the road, partly arising from bad drainage.

During the year 1856 there were fewer accidents of this description. This may be attributed to the greater attention given by Engineers to the permanent way, and to the introduction of the fished joint and of other improved methods of connecting the rails. In the year 1857, twenty accidents were caused by the neglect, or imperfect condition, of the permanent way. In four of these, it was neglected, and in five, it was constructed in a defective manner. Of these, the most glaring instances were;—one on the Newcastle and Tynemouth branch of the North-Eastern Railway, when a train ran off the rails in consequence of the road being too weak. One on the South-Eastern Railway, when an express train ran off the line at a place where the ballast was old and bad, and the sleepers were damaged. One on the Cockermouth and Workington Railway, where the train left the rails on a timber viaduct which had weakened trusses, worn-out sleepers, and weak rails, the spikes in some cases being absent, or broken, and the keys were worn out. In another, on the Great

Northern Railway, owing to the neglect of the original contractors for the line, in not providing sufficient waterway across it, the ballast was washed away during a flood, and two trains in consequence left the rails. On the Midland Railway, a broken chair, which had been left in, because the men were unable to get another, although they had applied for it, caused a train to leave the rails. On the Manchester, Sheffield and Lincolnshire Railway, an accident occurred owing to the Contractor having used inferior materials, the resident Engineer having omitted to enforce the terms of the contract, although attention had been frequently called by the drivers to the bad state of the permanent way. On the Great Northern Railway, a train left the rails on a curve near Boston, in consequence of the gauge of the line having been increased by the treenails of the outer chairs having been cut through.

In 1858, twenty-nine accidents were due to the state of the permanent way. On the South-Eastern Railway, a train left the rails on a curve owing to the use of wooden treenails. On the Ulster Railway, a train got off the line in consequence of the gauge being insufficiently secured; the rails were laid on longitudinal timbers, which were kept in gauge by transverse balks at from 10 feet to 14 feet apart, fixed by angle irons spiked to the longitudinals and to the transoms.

In 1859, fourteen accidents were due to the permanent way. In one on the London and North-Western Railway, near Leamington, a train left the rails on a curve, from the failure of the treenails, adding another to the too numerous instances which show the small resistance they offer, when placed on the outside of a curve, to the bursting pressure of a passing train, especially with the heavy engines and trains, and high speeds now in common use. Again, on the Glasgow and South-Western Railway, a train left the road on a curve where treenails, instead of spikes, were used. On the South-Western Railway, another left the rails, in consequence of the permanent way being too light for the weight of the engine and the rate of speed, and also on account of the joints not being fished. On the North-Eastern Railway a train got off the road, on the outside of the curve, in consequence of a key being wanting and the rails not being fished.

In 1860, several more accidents occurred from the defective construction, or condition of the permanent way. On the Great Northern Railway, a rail that had been turned, having been in a defective state before turning, gave way and threw an express train off the line. On the Edinburgh, Perth and Dundee Railway, an engine left the rails, on the inside of a curve, and went over an embankment, owing to the gauge being about an inch too wide, and the engine being unfitted for running on curved roads. On the Lancashire and Yorkshire Railway, a train left the rails on a straight, but unfished, part of the line; the treenails were found in this instance to be in a very defective condition, and appear to have given way under a strain of no greater severity than usual. On the South-Western Railway, a train left the rails, on an embankment near Honiton, in consequence of the road not being sufficiently consolidated to bear the speed of thirty-five miles per hour. On the same line, near Woking, the breaking of a turned rail, on an unfished part of the road, threw a train off the line; this accident was evidently caused by the failure of a worn-out road. A third accident occurred on this line near Gillingham; a train while at high speed leaving the line, owing to the weakness of the road, the distance between the sleepers being too great. From similar causes, and the ground being soft and marshy, a train on the London, Chatham and Dover Railway, left the rails. On the North Staffordshire Railway, the same kind of accident happened to a train, at a place where the joints of the rails were not connected by any of the modes now in use, and where the chairs were secured by wooden treenails in a very defective condition.

ROLLING STOCK.—The Author will now notice the accidents which proceed from defective, or neglected rolling stock. As regards locomotive engines, if considered solely in reference to the safety and efficiency of their working parts, it must be allowed, that in no part of the railway system, has there been so much actual improvement. Occasionally, however, an explosion takes place, due in some instances, to want of proper care in the selection of water for their use, and in others, to a faulty mode of staying the boiler. These might be prevented by more frequent inspection, by which the earliest intimation of any deterioration would be given, and the employment of weakened, or worn-out boilers would be discontinued. The working pressure should be marked on the boilers, so that there could be no excuse for exceeding it; and two whistles might be attached to the engine, one for ordinary purposes and the other, by its deeper tone, to warn the guard to apply the break. The driver and the stoker should be protected from the weather on all engines; accidents having happened from want of this provision. Though the Author admits, that great improvement has taken place in this part of the rolling stock, he believes, that the increased size and weight of the present class of locomotive is a serious error. The roads, in many cases, have proved too weak, and the bridges of the early railroads were constructed for much lighter weights. Such ponderous masses, at high rates of speed, are far less manageable than the earlier and lighter engines; and numerous accidents have occurred, from inability to stop them within a given distance. It is also certain, that in proportion to their weight, the earlier engines were much more efficient than the present machines, which when working a train, often require a considerable portion of their power to move themselves. Railways are not equipped with such powerful engines, because they are necessary for the ordinary trains; but because heavier trains have sometimes to be drawn. And whatever may be said, as to the advantage, or otherwise, of short and frequent trains, there can be little doubt, but that they must in time be adopted, for it must be remembered, the public is not made for the railway, but the railway for the public.

During the seven years under consideration, no less than ninety accidents occurred from defective construction, or neglect of rolling stock. In the same period, twenty-one locomotives exploded, each explosion being attended with more or less fatal results. The causes of these accidents were well known, and arose from neglect, or in the case of the older engines, from defective construction.

In the year 1854, eleven accidents were caused by the fracture of axles and wheel tyres, and no less than nine, out of the eleven, occurred on the Great Northern Railway. In the year 1855, five accidents resulted from the same causes. In one of these, on the North-Eastern Railway, a first-class carriage was dragged, with a broken tyre, for nearly three miles before the breakage was discovered, and the train stopped. In the year 1856, there were three accidents of the same character. In one of these, which occurred on the Great Northern Railway, on examining the tyre, it was found to have given way at the weld, in which a flaw had previously existed. The tyre was of Low Moor iron, and had been welded by Messrs. Rayner and Burn, but it gave way after running for three years. Having been twice in the lathe, it was reduced 1⅛ inch in thickness. On the Lancashire and Yorkshire Railway, a tyre on one of the leading wheels of the tender of an express train, broke entirely asunder. The fracture did not occur in the weld, nor near a bolt hole, and the metal showed no defect. The tyre was made by the Company, and it was freezing hard at the time of the accident. In an accident that happened on the Newcastle and Carlisle Railway, a tyre broke at the weld, which was very defective. It was supplied already welded by Messrs. Losh, Wilson and Bell of Newcastle, in 1854, and had been running with tolerable regularity up to the time of the accident. It had however been turned up in 1855, and had been tightened shortly before it broke, at which time it was found to be 1¼ inch thick. On the South-Eastern Railway an accident was caused by the breaking of the axle of the leading wheels of an engine which was twelve years old. On examination it was found that the axle had an old flaw in it, and had given way close to the boss of the wheel.

Many of the preceding fractures occurred during the winter months, owing, possibly, in some degree, to the rigid state of the permanent way in frosty weather; some were due to the use of bad iron, and others to defects either in the welding of, or in the mode of attaching, the tyres of the wheels. There is little excuse for the Resident Engineer who allows the road to be out of repair, or for the Manufacturer who uses bad iron in making axles and tyres. In welding tyres, flaws may exist, but with proper care and attention, even that great and serious source of danger may be lessened, if not altogether avoided. Steel, or partially steeled tyres, are now, to a certain extent, in general use, and tyres formed of a continuous ring, or unwelded piece of metal, are also successfully employed, and it is reported, that there is no instance on record of a tyre so formed, having been broken. It is very desirable, that the working of steel and partially steeled tyres should be tested, under various circumstances, with a view to discover and to remedy whatever defects may exist. The superior durability and excellence of these materials, when employed for other purposes, render it almost certain, that they possess nothing in themselves likely to render their employment undesirable.

It must be admitted that Railway Companies generally endeavour to procure tyres and axles of the best materials; but it frequently happens, that the benefits derivable from their use, are nullified by the manner in which they are employed, or by want of the attention which is requisite to maintain them in a proper and efficient condition. The serious results of accidents, occasioned by the breaking and detaching of tyres might be lessened, if not altogether avoided, by fastening them in such a manner, that they could not come off, even if broken in different places. Some methods of fastening on the tyres have, however, proved as fruitful a source of mischief as the unreliable and unsatisfactory plan of simply shrinking them on; and instances have occurred, where the failure has been the direct result of the means taken to prevent it. No doubt, there is a certain amount of difficulty in attaching tyres, in such a manner that the material shall not be injured by the process; but the method in use on the Brighton line, and that of Mr. Beattie, in which rivets are dispensed with, have been found to be very successful, inasmuch, as in cases where a tyre has been divided, it has run for a long time without being detached from the wheel. Mr. Brotherhood, and some others, have also introduced what appear to be simple and efficient plans for obtaining a similar result.[1] On the best mode of fixing tyres the Author would invite a discussion, as he has been informed that the tyres on many lines have not failed to any great extent.

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[1] The mode of fixing mentioned by Captain Tyler at page 14 of Reports on Accidents for 1860, seems to be the most secure of any within the Author's knowledge.—J. B.

The consideration of the treatment to which the tyres and the axles of wheels are subjected in actual work, must impress on every one the great attention they require. As before stated, the high speed now attained on most roads, and the indifferent manner in which the rail joints of some are maintained, subject both tyres and axles to a succession of rapid blows and jerks, which become an important cause of their deterioration. It is very desirable, that the mileage of each wheel should be recorded, so that the average duration of wheels may be ascertained, as well as the extent to which they are affected by form of construction, class of work, or permanent way. When a wheel has run a certain number of miles it should be immediately sent to the shops, whether it appeared to require examination, or not. This system might easily be generally adopted, as the rule, instead of being, as now, the exception.

There has been much improvement of late years in the quality and manufacture of axles. Considerable progress has been made by the Patent Axle Company, and Mr. Beattie, also, has introduced improvements, during the process of manufacturing, by which a greater amount of homogeneity is secured.

There is no division of railway plant in which want of system, or uniformity, is so strongly apparent as in the carriage portion of the rolling stock. The variety may be said to be interminable, and yet beyond external appearance and internal space, the railway carriages of the present day are not better, nor are they safer than those first constructed. The want of uniformity is a source of constant expense to Companies, by preventing simplicity of manufacture and maintenance. It is also often the cause of accidents, and it frequently contributes to render them disastrous. There is an evident necessity for a change; but more so as respects the train than the individual carriage. Each carriage should be strong in the longitudinal beams, the framing should be securely braced together, and the height of the buffers ought to be the same in all. Whereas carriages comprising a train have frequently wheels of various sizes, different heights of springs, and unequal heights of bodies. Hence, in a train at high speed, there is a diversity of motion defying description; and when a break-down, or a collision occurs, the carriages, as in several accidents that have taken place, do not strike the corresponding parts of each other, and their destruction ensues.

In constructing the carriages and rolling stock for railways, it should be the first care to have them uniform in height and size, and a train ought to be, as far as practicable, in effect and in appearance, one carriage. All the longitudinal beams in the train should be in the same line, and this should be the only part of the carriage capable of sustaining a blow. The buffers should be of such a form, that they would have a telescopic bearing in each other, and then be securely fastened; sufficient play being given for passing round curves. The present coupling in the centre should be greatly increased in strength, and the whole attachment should be such, that, in the event of a break-down, or a collision, the carriages would be kept truly in their position, and receive any blow along the entire line of framing. Again, should an axle or a wheel break, with a train thus thoroughly secured together, the crippled carriage would be borne up by those adjoining, until the train could be stopped, and accidents from carriages falling over would be unknown. In the event of an engine running off the road, with the carriages fastened as described, so long as the fastenings held good, it would make but little way, especially at an angle to either side, as the carriages would then lock between the rails, and prevent the progress of the engine. Another serious defect in the present system of construction is the buffer springs. They are necessary at stations; but, in cases of collision, their recoil is destructive to the carriages, and dangerous to life and limb; in fact, it may be safely said, that their reaction heaps injury upon injury. This can easily be remedied by the springs being adjusted to suit the ordinary blows at stations in shunting, &c.; but to prevent the reaction from heavier blows, as in a collision, a simple catch, which could be readily released, should be introduced.

MANAGEMENT.—It has been previously noticed, that 76 per cent. of the total number of accidents arise from defective management. It is hoped that a reduction of this fearful per centage will be earnestly attempted and successfully carried out, and the Author trusts, that the suggestions he has to offer on this head may not be considered altogether unworthy of attention. He proposes to deal with this branch of the subject under the following subdivisions, and in the following order:—Speed of trains; unpunctuality in the times of starting and the rate of running; semaphore signals; signals by telegraph; communication between engine driver and guard, or conductor; break power; negligence of servants, their hours of working, their payment, and their insufficient number.

In reference to the speed of trains it may be said, that provided the road and the rolling stock are good, it is not the speed at which trains are appointed to be run, that need be feared, as a probable cause of accident; but their not being run as appointed. In the case of most accidents arising from excessive speed, it has been found, that the driver has lost time, and, that in endeavouring to recover the loss, he has been running at the time of the accident at a considerably greater speed, sometimes twenty miles per hour more, than the rate appointed. With trains running at these furious speeds, both the rolling stock and the road are strained beyond their powers of endurance, and the result is the failure of some part of the machinery of the train, or the giving way of the road, so that the train leaves the rails.

Punctuality, in the times of starting, and uniformity in the rate of running trains, are among the most important matters connected with the working of railways, inasmuch as by punctuality, safety, so far as human foresight is concerned, is ensured; whilst unpunctuality forms a serious element of danger. In 1854, on the North British Railway, a goods train waited one hour at Edinburgh for a guard, and was run into by the mail. On the Great Northern Railway, in the Welwyn accident, only one train out of four which were concerned kept its time, and this one ran into another which was an hour too late. On the same line in a collision at Hatfield, the three trains concerned were, respectively, 3 hours 10 minutes, 2 hours 47 minutes, and 1 hour 40 minutes late. In an accident on the London and South-Western Railway, a passenger train timed to run at twenty-six miles per hour, was started two minutes after a goods train, timed to run at sixteen miles per hour, and as a certain consequence the passenger train ran into the goods train, before it had gone four miles from the starting point. The number of instances in which unpunctuality, and the starting of one train too soon after another, have been the cause of accidents, are far too many to be referred to separately. The Author need, however, only allude to the Clayton tunnel accident, to illustrate his remarks on this head.

A general rule has been laid down, that five minutes ought to elapse between the starting of trains from a station, but this cannot be made generally applicable, as so much depends on the class of trains succeeding each other; such as their rates of speed, or their being stopping trains, or otherwise. In many instances an interval of five minutes may be enough, but in others it is manifestly insufficient, for though trains may be started from a station at the stated intervals, they will, from various causes, be unable to preserve the same distance between each other. More attention is required to this point than to that of their starting. The system of working the traffic of a railway, by allowing an interval of time between the trains, is unsatisfactory and dangerous, and far inferior to that of allowing an interval of space. The time interval does not give the least security, nor does it provide in any way for obstructions, or for accidents to the preceding train; but, as is invariably found, it produces the very result it was intended to prevent, by not forewarning the drivers of the exact position of the preceding train. By the system of the interval of space, no following train would be allowed to pass a station, until the one before it had attained its proper place on the line, and due notification of that fact had been received at the station.

The irregularity of excursion trains is a fruitful source of accidents. Indeed, during the summer and autumn, whenever a railway accident occurs, it is. almost invariably occasioned by an excursion train. There can be no doubt, that if, during the excursion season, all the ordinary trains were run at lower rates of fares, punctuality and order could be maintained on the road, and the necessity of interpolating the ordinary traffic with large, unmanageable, and unpunctual trains, would be entirely done away with; the public would hence feel greater security in travelling, and, as the time and convenience of greater numbers would be suited, the traffic would be much increased. The principal element of danger in excursion trains is the practice, which prevails, to a great extent, of running them without any time-table, or fixed time on the road. The drivers when started are ordered to make the best of their way to the end of the journey; consequently they may be a greater, or a less time on the trip, without their position, at any part of it, being exactly known. Difficulties undoubtedly exist in running coal, or mineral trains to a fixed time-table, as the work varies daily, and the time occupied in adding, or taking off the waggons, and in shunting operations, is uncertain; but a great improvement might be made by the more general use of the electric telegraph, and a better system of signaling arrangements.

During the seven years, from 1854 to 1860 inclusive, as many as eighty-eight accidents happened from the use of improper, or inefficient signals. As fourteen occurred in 1860, it is apparent that this subject has not yet received the attention it demands. Accidents have been caused by the total want of signals, especially at sidings, others have arisen from their defective form, or from their bad position. In some cases, the signals have been hidden by the surrounding objects, and in others, they have been unconnected with the facing points,—whereas it is most desirable that junction signals and points should be worked simultaneously by one man. Many accidents have occurred in connection with distance signals. In some cases they have been placed so near to the station, that the driver has been unable to stop within the space allowed. In an accident at a junction, only one semaphore was used for both lines. If a junction is to be worked safely, it is necessary to provide at least separate main signals and separate distance signals for each line of railway. The semaphore now in general use is sufficient for signaling purposes, provided it is properly placed, kept, worked, and obeyed. The Author would place more confidence in its being worked by competent men, than on any self-acting contrivance, the simplest and best of which, is liable to get out of order. For, although signals may be made to work, both as self-acting, and by hand, it has been seen, on too many occasions, that when the self-acting gear fails, the man, through want of practice, fails also. Of this, the accident at the Clayton tunnel is a lamentable proof. It may be thought unnecessary to add, that it should be the duty of some responsible officer to look after the signals, and to see that they are kept in good working order; yet it is a fact, that owing to its being no one's particular duty to attend to them, they have been allowed to get into such disorder as at last to become quite useless, and that an accident has been the result. In one accident the non-explosion of a fog signal was the cause, showing how important it is that none but the best should be employed, and that they should be kept dry until they are wanted.

The system of working the traffic by the use of the Electric Telegraph, has not yet received that attention from Railway Companies which its importance deserves, and which a daily increasing amount of traffic demands. By the proper and judicious employment of this valuable adjunct to the railway system, all accidents, occurring to trains on the road, might be prevented, at least all those arising from collision, and the effects of accidental, or other derangements to the trains or the road. If the line was divided into sections, by the establishment of telegraph stations and signals, with properly instructed and steady men, so that a train would be prevented from entering any section, until the preceding train had passed the section in advance, collision would be impossible, except such as might result from disregard of the signal. In case of a train breaking down, or getting off the rails, or becoming unable to proceed, it would prevent any accident to following trains, and would give early information at both ends of the section, of the line being blocked. For instance, the non-appearance at its proper time, at the end of a section, of a train that had been signalled as on it—which might be caused by the train leaving the rails and blocking both lines—would enable the following train, and the one proceeding in the opposite direction, to be detained, until the cause of the non-appearance was removed. By this plan, accidents from collision would be prevented, and a proper interval between the trains would be secured, in spite of unpunctuality. It would, however, be necessary that special wires should be reserved for the service, and that the instruments should be of the simplest construction. The Author has recently examined a plan for enabling a telegraphic signal to be sent from a station to the driver of an engine approaching it at full speed. This is effected by placing three insulated iron bars between the rails, and connecting them, by means of two ordinary telegraphic wires, to an instrument and battery at the station. Two broad flat bars, with a hinged joint at the ends, are placed on the front or hind buffer plank of the engine, from each of which a wire runs to a signal dial placed on the fire-box in front of the driver, and on these bars touching the insulated bars between the rails, the signal sent from the station is repeated on the engine with unerring accuracy.

The need of a communication between the engine driver and the guard or conductor, is sufficiently evidenced by the number of accidents that have arisen from the want of it. The drivers and firemen are necessarily occupied in looking forward along the road, and in attending to their engines and the signals; and, although they frequently glance back at the train, it generally happens that when they do so, no communication is required, and that in the interval during which their attention is diverted, an accident happens, which a means of communication from those in the train to the men on the engine, might possibly have averted. There can be no sufficient reason why this state of things should continue, seeing that there is no mechanical difficulty to overcome. Communications have been in daily use on the South-Western, the London and Brighton, and some other lines; but to render their application effective, a conductor should be specially appointed to watch the train. The communication ought to be under his control, and he should start the train from each station by its means, to prove that the machinery is in working order. So many instances have occurred in which such a means of communication has been urgently needed, that all prejudices against it ought to be laid aside, and it should be universally applied. On the Great Western Railway, the plan of placing a man seated in a species of box, attached to the tender, with his face towards the train, has been employed for some years with good results. Whilst the train stops at stations, his duty is to see that the axle-boxes, of all the carriages in the train, are furnished with a due supply of grease. It is true, that in case of a fog, his utility as a watchman is diminished, but this system deserves to be noticed, as a step in the right direction. The plan, followed on most lines, is that of making the guard sort luggage and parcels while on the journey. Sometimes he is placed behind a wider carriage than his van, so that his view is obstructed; or, if the look-out window is in the roof of the carriage, his view is obstructed by a roof loaded with luggage. It cannot, therefore, be expected that, under ordinary circumstances, the guard is likely to prove of much use, as a means of informing the driver when anything is wrong with the train. On Continental and American railways, one man is sent with each train whose duty it is to attend to the luggage and parcels alone. On the Continental lines, men are also employed for the sole purpose of keeping a good look-out along the line, being seated outside the carriages, one man being allowed for every four carriages. In America, there is usually one breaksman to every two carriages; and, by means of a cord to the bell on the engine, the guard can readily communicate with the driver; or, if preferred, he can walk to the engine through the central passage of each carriage in the train.

The subject of break power requires especial attention, many lives and much property being hourly dependent, in a greater, or less degree, on the power and efficient state of the breaks. It has been found, that most of the collisions which have occurred, might have been prevented, had those in charge of the trains possessed the power of stopping it within a few hundred yards. This is more particularly necessary, on account of the high speeds and heavy trains now adopted on all lines. It is, therefore, essential that there should be ample break power to each train, and whatever system is adopted, it must be powerful, simple, and capable of being applied in the shortest possible time.

The system at present in general use, of placing break vans at various parts of the train, with a guard in each, adds to the dead weight of the train, without increasing the paying load. At the same time it adds to the wear and tear of the rails and tyres, by creating a concentrated retarding force at particular points in the train. In lieu of this, a regularly distributed force is needed, or one which acts equally, and, at the same time, on all the wheels throughout the train, but the power should not be increased to such an extent as to act as a 'skid.' In point of economy, this system of 'continuous breaks' as it has been called, has another great advantage; it enables one man to apply a large number of breaks at the same time, and renders the employment of several men with each train unnecessary. But the most important advantage arising from its employment is, that trains can by its means be kept more under control, and be brought to a stand within a very limited distance. The risk of collision is thus considerably reduced, and the time now lost, in stopping the train at stations, is so much lessened, that a great saving on each journey is obtained, especially on lines where there are many stoppages. Of the various plans of continuous breaks which have been tried, those of Messrs. Newall, Fay, and Chambers, seem to be the most practical, and are more, or less in use on several lines, where they are said to be very efficient. A very objectionable feature in the break which is ordinarily used, is that of applying the block on one side of the wheel only, instead of on both sides. The effect of a break block being suddenly brought with great force in contact with one side of the wheel is very prejudicial to the axles, tyres, brasses, and horn plates; and being a very unmechanical arrangement, should be abandoned.

The negligence of servants, their payment, and their hours of working, are also matters of the greatest importance. Most of the accidents caused by negligence may be traced to ignorance or to inefficiency. The wages usually given by Railway Companies are too low to command the services of men of intelligence, steadiness, and self-reliance, and in consequence inferior men are employed, who are incapable of appreciating the importance and necessity of executing their duties with promptness and exactitude.

Hence occasions arise, where by the blunder of a single inefficient man, many valuable lives are lost, and property to a large amount is destroyed. Those who appoint such men from parsimonious motives, should consider, that in attempting to save a few pounds, they risk thousands. The interests of Railway Companies would be greatly promoted, if the servants regarded their employment as the most desirable and advantageous that could be obtained, and looked upon dismissal as a calamity. This might be done at far less cost than that of making good the damage caused by accidents, arising from the employment of inferior men. The best-conducted men should be entitled to a pension after a certain term of service, and also an allowance during sickness, or when laid up from the effects of injuries received while in the Company's employ. In 1857, a French Commission, appointed to investigate the causes of railway accidents, gave particular attention to this question, and recommended in their report, that the law should assimilate them to civil servants; that extreme care should be taken in their selection; that a superannuation fund should be formed, and that the rules for working should be clear and simple, and not calculated to overburden the memory. One great means for reducing the number of accidents arising from negligence, would be to fix an individual responsibility upon all, from the highest to the lowest, concerned in the working of railways. In numerous cases, in which subordinate servants have been discharged or punished for neglect, it has been quite as much the fault of the superior officers. Habitual infringement of rules has often been permitted, with the full knowledge of the managers, until the occurrence of an accident, when reference has been made to an obsolete code of regulations, and the offenders have been summarily punished.

The overworking of railway servants is another serious element of danger. It arises from many causes, the principal and most easily remedied being the insufficient number employed. The number of hours, during which they are kept on duty, cannot fail to render them less vigilant. In the course of inquiries, it has been found, that drivers have in some cases been employed for a period of seventeen hours daily, and they have been known to be on duty as much as twenty-six hours and even thirty hours continuously. An insufficient number of servants also tends to unpunctuality; to being obliged to make use of unqualified, or inexperienced persons, for the performance of onerous duties; and to the use of self-acting apparatus, which however useful when it receives proper attention, becomes, in such cases, positively dangerous without it. This is more especially the case with self-acting points, which the Author would remark should always be attached to a signal, moved by the lever which shifts the points, so as to indicate by day and by night whether they are placed in the right position.

By defective management, more money is sometimes lost in a moment, than can be gained in a year. This being the case, it appears unaccountable, that some earnest and united efforts are not made by Railway Companies to devise means for obtaining an improvement. It is most indefensible, that after an accident has shown a cause of danger, any Company should either for convenience, or to save a trifling outlay, permit it to remain. The Author feels that no excuse will be needed for having devoted so much space to this part of the subject, when it is remembered, that during the seven years under consideration, no less than 1,041 accidents were due, in a greater or less degree, to the effects of mismanagement.

The Author proposes leaving the question of the bearing of existing legislation to be dealt with by Captain Douglas Galton. He would however observe, that government interference is not likely to render railways safer, or more available to the traveller; and, that it would be better to rely on the consideration and calm reflection of those immediately interested in these enterprises, especially, as from the great expenses attendant on accidents, and the heavy amounts awarded by juries as compensation to individuals for injuries, or to their survivors in case of loss of life, directors and shareholders would naturally desire to render this mode of travelling as safe as possible.

The Author, in conclusion, would express the hope, that from what has been advanced, and from the discussion that may take place, beneficial results will ensue. In bringing the subject before the Institution, his object has been to help to decrease, as far as human foresight can, the number of railway accidents, and at the same time to place railway property on a safer, and on a better commercial footing than at present, and if what he has done, should be the means of preventing one accident, or of saving one life, he will be amply repaid for his labour.

April 1, 1862.

JOHN HAWKSHAW, President,
in the Chair.

No. 1,067.—"Railway Accidents—showing the bearing which existing legislation has upon them."[1] By Captain DOUGLAS GALTON, R.E., F.R.S., Assoc. Inst. C.E.

THE subject of Railway accidents was laid before the Institution in the year 1852, in a Paper by Captain Huish,[2] (Assoc. Inst. C.E.). Railway communication and railway management have, however, been largely developed since that period; and a recent decision in a court of law has induced greater attention to the question of compensation paid for accidents. The time would, therefore, appear to have arrived, when it is desirable, that the subject should be again brought forward for discussion.

The length of railway communication open in the British Isles, at the end of 1860, was 10,433 miles, upon which 163,435,678 passengers were conveyed during the year. Of these 1 in 5,447,855 were killed, and 1 in 362,079 were injured, from causes beyond their own control. It would moreover appear, from the public returns, that during the seven years ending 31st December 1860, there were 116 passengers killed, and 2,832 passengers injured, from causes beyond their own control, making a total of 2,948 sufferers during the seven years.

The Author has obtained returns from a limited number of Railway Companies, showing the amounts paid as compensation during the last three, or four years, and applying the figures to obtain an average, in comparison to the number of passengers conveyed on the several railways, it may be assumed, that an average sum of from £100,000 to £120,000, has been paid annually by Railway Companies, as compensation for railway accidents. If this sum be divided between the number of passengers, and if the average number of miles travelled by each passenger be brought into the calculation, it may then be assumed that an insurance of one-twenty-fourth part of a farthing per passenger per mile would, on the average of all the lines, cover the cost of railway accidents. One Company, however, with a capital of about

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[1] The discussion on this, in conjunction with the preceding Paper on the same subject, by Mr. Brunlees, was continued over portions of four evenings, but an abstract of the whole is given consecutively.

[2] *Vide* Minutes of Proceedings, Inst. C.E., vol. xi., p. 434.

£14,000,000, appears to have paid, on an average of four years, one-fourteenth of a farthing per passenger per mile; but on an average of fourteen years, the payments for compensation by that Company did not exceed one-twenty-fifth of a farthing per passenger per mile. Another Company appears to have paid, on an average of four years, as much as one-ninth of a farthing per passenger per mile.

In some special cases, the amounts paid by a Railway Company have been very large. For instance, in the case of the collision at Atherstone, on the London and North-Western Railway, in November 1860, the Company paid £17,964 as compensation for personal injuries and for cattle killed. The accident which occurred at Nuneaton, in May 1858, from a train having been thrown off the line, by a cow which had strayed on to it, cost the Company for compensation £5,375 and for law expenses £4,095, making a total of £9,470. For the collision at Hitchin, between a Great Northern and a Midland train, the Companies paid £13,440, and for the accident at King's Cross, in May 1860, from a train running at too great a speed into the station, and coming into contact with the buffer stop, owing to the guard having omitted to apply his break, the Company paid £10,122. On the South-Eastern Railway, the Company paid in compensation £7,489 for the accident which occurred at Chilham, in June 1858, from a train leaving the rails on account of the fracture of a crank axle; and for the collision which occurred at Lewisham, in 1857, the same Company actually had to pay the enormous sum of £27,067, in addition to the cost of injury to the rolling stock.

Besides the money paid as compensation to the passengers, almost every accident involves the injury to and often the death of railway servants; and the men injured have to be supported by the Company during illness, or their families have to be compensated, if they are killed. Large sums have also to be paid for injuries done by accidents to merchandise and cattle, and for the destruction of rolling stock. Railway accidents cause, therefore, a serious loss to the community at large.

Conveyance by railways would, however, appear to be safer than by any other mode. It has been found impossible to obtain reliable information as to the number of coach accidents in this country. But the returns of the 'Messageries Impériales' show, that in a series of years the number of passengers killed and injured, from causes beyond their own control, was 1 in 28,000; whilst from the latest comparative returns of railway accidents, the number of passengers killed and injured from causes beyond their own control, would appear to have been on British railways 1 in 334,000; on Belgian railways 1 in 1,600,000; on Prussian railways 1 in 3,000,000; on French railways 1 in 4,000,000. The greater comparative safety of foreign over British railways can be clearly traced to differences in the conditions of the traffic and management, and in the habits of the people, which lead them to allow the convenience of the Railway Companies to be consulted in the running of the trains, before that of the travelling public; but it would extend the limits of this Paper too far to enter upon these considerations.

There is, however, little satisfaction in showing that railways are safer than other modes of conveyance, unless it can be shown, at the same time, that none of the accidents which occur could have been prevented by reasonable precautions. In endeavouring to elucidate this question, the first point which arises is the extent to which the amount of traffic on the several lines influences the accidents. An analysis of the returns on British railways shows, that there are lines whose total length amounts to one-sixth of the railway communication of the country, upon which no accidents occurred during ten years; and that the average number of passengers per annum travelling on those lines was under 3,000 per mile. Whilst upon the other lines, or those upon which accidents have occurred during the same period, the average number of passengers was over 14,000 per mile per annum. These general averages show, that lines of small traffic are comparatively safe. But, although the amount of traffic has a material influence on the safety of the different lines, many other causes enter into the question.

The following Table shows the ratio of traffic to the degree of safety upon certain specified railways on an average of seven years:—

Proportion of the Killed and Injured to the Number Conveyed.	Name of Railway.	Average Number Conveyed per Mile.	Per Centage of Goods Traffic to Total Traffic.	Collisions.	Other Accidents.
1 in 180,365	Lancashire and Yorkshire . .	232,621	60	25	15
1 in 212,067	London and North-Western .	93,764	53	31	23
1 in 252,158	Caledonian	126,694	62	7	6
1 in 257,051	Midland	94,799	64	23	14
1 in 285,237	Eastern Counties.	78,456	47	15	5
1 in 289,979	South-Eastern	244,500	25	10	15
1 in 350,200	North-Eastern	66,660	62	21	16
1 in 433,583	London and South-Western .	127,942	26	18	16
1 in 535,324	London, Brighton, and South Coast	283,577	19	6	6
1 in 601,679	Edinburgh and Glasgow . .	84,533	49	2	2
1 in 676,235	Great Western	84,024	38	10	6
1 in 702,470	Bristol and Exeter	73,056	33	4	4
1 in 742,429	Great Southern and Western .	20,183	33	..	2

From this Table it is clear, that traffic alone does not determine the number of accidents. In order, therefore, to arrive at a clear understanding of the question, it is necessary to analyze the causes of each accident in detail. This is a course which the Author followed for some years, whilst at the Board of Trade, and he has continued the analysis down to the end of 1860, for the purpose of this Paper. During the seven years ending on the 31st December 1860, there were 534 accidents to trains reported upon by the Inspecting Officers, in which 2,912 passengers were killed, or injured, from causes beyond their own control. These accidents may be generally classed as follows:—

——	Number of Accidents Reported upon by the Inspecting Officers of the Board of Trade.	Sufferers.
Engines, or Carriages leaving the Rails, or fractures of Machinery	135	313
Collisions of all classes	319	2,532
Other causes	80	67
Total	534	2,912

The causes which appear from the reports of the Inspecting Officers, to have contributed to occasion the accidents may be thus classified;

1. Causes which could not be guarded against.
2. Causes which were within the control of the managing, or working staff, employed in conducting the traffic of the line.

The general results may be thus stated:

Number of Accidents reported upon by the Inspecting Officers of the Board of Trade, the Reports on which have been analysed.	Sufferers by Accidents.	Cases in which the Accident could not be guarded against.	Cases in which the Accidents were due to Causes within the control of the Management.		
			Cases attributable to the Works, or Rolling Stock.	Cases attributable to the System of Working.	Negligence of Inferior Servants.
534	2,912	82	388	247	207

In explanation of this Table it is to be observed, that in the case of many accidents there has been more than one contributing cause:—for instance, the negligence of a servant may have contributed towards the accident, but defects in the system of working, or in the condition of the road and trains, may also have contributed to cause the accident. In such a case each contributing cause appears in the Table. A further analysis shows, that the large majority of those accidents may be classed under two principal heads, and the following instructive Table shows the contributing causes of the accidents which fall under the two heads;—

———	Number of Accidents reported upon.	Number of Sufferers.	Cases in which the Accident could not be guarded against.	Cases in which the Accidents were due to Causes within the control of the Management.		
				Cases attributable to the Works, or Rolling Stock.	Cases attributable to the System of Working.	Negligence of Inferior Servants.
Accidents from Engines and Carriages leaving the Rails, or from fractures of Machinery	135	313	59	98	15	17
Collisions of every description . . .	319	2,532	16	222	219	183

These figures show clearly, that a very large proportion of so-called accidents are due to preventible causes. In the case of accidents from fractures of axles and tyres, and from engines and carriages leaving the rails, it appears that somewhat under one half of the accidents were attributable to causes which could not have been guarded against. But out of a total namber of 319 collisions reported upon by the officers of the Board of Trade, only 16 were attributed to purely accidental causes; and of the 303 remaining cases there were only 183 into which the negligence of the inferior servants entered as a contributing cause. The remaining 120 collisions were entirely attributable to the manner in which the traffic was conducted, and ought therefore not to have occurred.

1. Accidents which could not be guarded against.—Of the 82 casualties classed as accidents which could not be guarded against, the greater number were cases of fractures of axles, tyres, rails, and other portions of the machinery of the trains, or of the road. In cases of fractures of tyres, or axles, where no flaw has been visible before the occurrence of fracture, and when every care has been taken to obtain good material and manufacture, the primâ facie conclusion would be, that the accident could not have been prevented. The question must, however, arise, whether the form of axle, tyre, rail, or piece of machinery fractured, has been that best adapted to resist the strain to which it was subjected, or whether the material has been overtasked. Much has, no doubt, been accomplished by Railway Engineers in improving machinery; but much more remains to be done to diminish the number of ac-

cidents, and to mitigate the severity of the results. The best and safest form of tyre for a railway wheel has not yet been definitely settled; the wheels and axles can scarcely be said to be mechanically satisfactory; and the form of break in general use is imperfect. These and many other points, which should have been long ago settled by continued scientific and experimental inquiry, are still undecided. Individual Railway Engineers must possess an enormous number of facts bearing upon every point of railway construction; but the facts collected by one experienced person are often not collated, or published, and are consequently not available for others to refer to. The result is, that time and money are frequently wasted by a Railway Engineer, in repeating experiments upon questions which may have been determined previously. In Germany and in Austria an Association of all the Railway Companies has been formed, for the purpose of collecting statistical and engineering information from the different railways, and for collating and rendering it available for the use of all the contributing Companies. Each Company is represented by one, or more of its officers; and committees of the members are appointed to investigate and experiment on suggested improvements in railway construction. The results are collected and communicated to each of the Companies. The Association circulates periodically a series of principles to be observed in railway construction, and these are adopted on new lines, and are gradually introduced, as opportunities occur, on the old railways.

2. NEGLIGENCE.—Of the 183 cases in which negligence of the servants contributed to cause the accidents, only 35 were attributable to negligence alone. In the other cases, the carelessness alone of the servant would not have occasioned the accident, had not some defect of system, or want of the requisite auxiliaries to safety, existed, which also contributed to cause the mishap. Simple negligence cannot be entirely prevented, as in instances like the following:—On the London and North-Western Railway a train was thrown off the rails, because the platelayers omitted to put in a rail which they had taken out. On the North-Eastern Railway an accident was caused by the platelayers leaving a rail across the line. In more than one case trains have been run at too great a speed into a terminal station, and have come in contact with the fixed buffers, solely because the guards omitted to put on the breaks. Such cases as these will always occur, for so long as human agency is resorted to, men will now and then become flurried, or will err in judgment, or be subject to forgetfulness. As an instance of this may be quoted the accident at Hitchin, in 1859, where the signalman at the junction between the Great Northern and the Midland Railways, first gave a signal to the Midland train to advance, and

when it had got into motion and could not be stopped, he changed it to a danger signal, and signalled forward the Great Northern train; the natural consequence was that a serious collision ensued.

In several of the cases in which negligence has been one of the contributing causes of accidents, the negligence has been attributable to the defective arrangements of the Company. For instance, in the case of an accident caused some years ago by an engine-driver running past a danger signal — the engine-driver and the fireman had been out on the engine for thirty-six consecutive hours. Pointsmen and enginemen have, in some cases, been regularly kept on duty for seventeen, or eighteen hours out of the twenty-four; and sometimes the rule has been, that for one day in each week a pointsman shall remain on duty for twenty-four hours at a time. Negligence in cases of overwork is not chargeable as a fault against the individual servant, but against the Company. The following is another instance, in which faulty arrangements were mixed up with negligence:—A collision occurred between a goods train and a passenger train, under the following circumstances; the goods train, which was four hours late, was started from a station, against the regulations, ten minutes before the express train was due, because the express train was generally unpunctual. The goods train was shunted on to the opposite line, contrary to the regulations, to allow the express train to pass, at a station where there was no siding, because the signals were defective at the next station where there was a siding. A collision almost necessarily occurred between the goods train and a passenger train travelling on the main line of rails on to which the goods train had been shunted.

Many of the cases of accidents from trains passing on to a wrong line through facing points, in consequence of the latter having been erroneously set through carelessness, would not have occurred had an indicator been attached to the points, to show, at a distance, in which direction the points were set. Acts of negligence must be punished, and the law affords Railway Companies the means of punishing, by a "fine to the extent of £10, and imprisonment to the extent of two months, on summary conviction, before a magistrate, any servant who shall wilfully, maliciously, or negligently do, or omit to do, any act whereby the life, or limb, of any person passing along, or being upon the railway, or the works thereof, shall be, or might be injured, or endangered; and whereby the passage of any engine, carriage, or train shall be, or might be obstructed, or impeded." There are about 190,000 railway employés; and of these there are nearly 20,000, the careless act of any of whom might create a frightful accident. But these men are directly responsible for their acts, and are easily amenable to punishment. The comparatively small number of accidents which are traceable to negligence of the inferior servants alone, is a strong evidence of the efficacy of this direct responsibility. Dismissal is a punishment frequently resorted to; and would be probably the severest punishment to which railway servants could be subjected, if employment on a railway possessed preponderating advantages over other employments, and if a railway servant dismissed from one line were not eligible for employment on another line. In order to attract good servants, and to retain them, the French Railway Companies have almost invariably organised for their lines a "caisse de secours," out of which payments are made in cases of accident, and from which some provision is made for the servants in their old age.

Inasmuch, however, as the human instruments, with which Railway Companies must work, are liable to failure, however excellent be the system of working, and however great be the care taken in selecting and managing them, it seems no doubt a hardship on Railway Companies, that a simple error of a good servant, when the man was not overworked, and when the arrangements and working were well regulated, should be visited on the Company in the way of compensation more severely than the fracture of an axle, or a tyre, or the failure of an inanimate piece of machinery. It is, however, practically impossible to entertain such questions. The Company must be held responsible for the acts of its agents; but it may be worthy of consideration, whether the same responsibility should not invariably attach to the failure of machinery, as to accidents which have been classed as preventible.

3. Causes of Accidents within the control of the Management.—Out of the 534 accidents, the causes of which have been analysed, there were 388 cases in which the accident was wholly, or partially attributed to defects in the condition of the railway, or of the vehicles, or to the absence of the requisite auxiliaries to safety, such as signals, breaks, &c.; and there were 247 cases in which a defective arrangement for working the traffic, or a laxity of system, contributed to cause the accident.

It would extend the limits of this Paper too much to quote the numerous cases which are described in the Reports of the Inspecting Officers, and it is beyond its scope to enter into the merits of special forms of road, of breaks, or of signals, or other mechanical contrivances. The Author will confine himself, therefore, to alluding, cursorily, to a few instances, which generally illustrate the argument. In one case, when a train ran off the line, in consequence of the defective condition of the road—the sleepers were decayed, the chairs were loose, the ballast had nearly all disappeared, and the drains were closed up; yet trains were habitually travelling over the line at a speed of fully 40 miles per hour, until the attention of the Company was called to the state it was in, by the occurrence of this accident. In many cases, when accidents have occurred in consequence of the absence of signals at a station, or at a siding, the deficiency has arisen from a change in the condition of the traffic. At the opening of the line, the signals placed at the stations were sufficient for the then wants of the traffic. But new sidings were added, and a largely increased traffic was developed. No thorough re-consideration of the arrangements necessary for safety took place until the accident occurred. In one case of an accident due to the failure of a self-acting signal, it appeared that the failure was occasioned by the signal not having been properly looked after for some time previously. In numerous instances it has appeared, that engine drivers have been habitually permitted to disregard caution, or danger signals, until an accident has occurred, and then the rules which they have been allowed for some time previously to neglect, have been quoted against them. Goods and cattle trains have been habitually permitted to be started a few minutes in advance of passenger trains, until an accident has occurred, when the rules, whose violation had been previously overlooked, have been brought forward as a justification of the Company. Heavy excursion trains have been 'timed' to start at short intervals apart, and have been directed to proceed rapidly; whilst the amount of break-power provided has been so small, as to be quite insufficient to stop the train within any reasonable distance. Trains have been 'timed' to run at a high speed over lines unfit for even a low speed, and the carriages have left the rails. In some cases the original construction of the line, as sanctioned by Parliament, has been in fault. The crossing of one railway by another, on a level, and junctions between railways, have been placed in positions in which they should not have been allowed.

In considering these questions, however, weight must be given to the fact, that the railway system has been, and is still, a vast experiment. At its commencement the road, the rolling stock, and the mode of working were all new; and the system is even now in process of development. What was considered perfect yesterday is looked upon as antiquated and unsafe to-day; and the improvements introduced at great expense to-day will probably in their turn be superseded to-morrow. When the railway of 1840 is compared with that of 1860, it is found that the whole machine has been renewed. But with every allowance for the 'newness' of the enterprise, it will be found, that the Reports of the Inspecting Officers are full of instances, in which properly exercised care and foresight would have prevented the accident. Good rules are easily made. It is not for the want of them that accidents have occurred, but for the want of a continued enforcement of those rules, and of a close examination into the details of the manner in which the traffic is worked. Without constant watching, unsafe methods of conducting the traffic infallibly creep in, from thoughtlessness, or ignorance amongst the servants, in whose hands those details are left, and whose habits do not lead to those methodical arrangements which are essential to safety in working.

In France and in Germany, the people have a habit of methodical administration which the British do not possess; and it is probable, that one of the causes of the French and German railways being more free from accidents will be found in the rigidly methodical manner in which every detail of working is treated.

The system upon which railways are managed in this country is in some respects to blame for the 'shortcomings' to which preventible accidents are attributable. A railway is several hundreds of miles in length. It has cost several millions sterling, and it employs servants who may be reckoned by thousands. Its profits depend, as in any other business, on attracting custom by civility, thoughtfulness, and reasonable charges, and on carefully practised economy in working. This vast property is often managed by Directors who meet only occasionally; who give up only a portion of their time and thoughts to the concern; and who frequently absorb the time and fetter the responsibility of the managers appointed under them. On one railway, which extends over nearly 1,000 miles, there are thirty-two Directors, not one of whom is at present paid sufficient to entitle the Company to demand his whole time and thoughts. A private concern could not go on under such arrangements. Besides, those who are specially charged with the duty of looking after the safety of the traffic do not occupy, as a rule, such a position, or status, in the Company as the importance of their charge calls for; nor is there, generally, that gradation of responsibility which alone enables the Directors to hold their officers responsible for results.

Parliament has, upon more than one occasion, discussed the subject of railway accidents. Mr. Cardwell's Committee in 1853 examined very closely into the question. That Committee arrived at the conclusion, that any interference with the details of management was undesirable; but recommended that there should be placed upon those in whom the management of railways was vested a greater degree of responsibility than the law at present admitted, and proposed that each Railway Company should have an Engineer, a Locomotive Superintendent, and a Traffic Manager, who should each be responsible for the proper working of his department. A Bill to give effect to this proposal was introduced into Parliament; but obvious difficulties in the way of dealing with the question in this manner, caused it to be given up.

In 1857, Mr. Bentinck obtained a Committee on Railway Accidents. The Committee recommended, that a law should be passed to compel all railways to be worked by the Electric Telegraph, and that punctuality should be enforced, by enabling passengers to obtain prompt and cheap redress, in the recovery of penalties in every case of want of punctuality in the departure and arrival of trains at every station. Parliament has not acted upon this Report. The enforcement of punctuality on Railway Companies would be a great benefit to the public, as well as to the Railway Companies themselves. But there would be practical difficulties in the way of equitably reducing the recommendations of Mr. Bentinck's Committee into a law; for circumstances occasionally arise, over which a Railway Company cannot have any control, but which prevent a train from being punctual; and in such cases it would be unjust to the Company to give the public more claims to compensation than they now possess. The other recommendation of Mr. Bentinck's Committee—that Railway Companies should be compelled to work their lines by means of the Electric Telegraph—would be an interference with the details of working, and would, therefore, introduce a new feature into Railway Law. At the present time, Railway Companies are free to construct and to work their lines in any manner they choose, provided only that the construction is such, at the opening, as in the opinion of an Inspecting Officer of the Board of Trade, will enable the then anticipated traffic to be worked without danger to the public. When the line has been opened for traffic, Government only possesses a power of making regulations at the junctions of the lines of two Companies, and in cases where the lines interfere with landowners' interests, as, for instance, at level crossings. But the control over the manner of working the line is left by Parliament entirely in the hands of the Railway Company. The Company in undertaking the duty of carriers becomes liable under the common law, and under Lord Campbell's Act, to compensate persons injured, or the relatives of persons killed, by the negligence either of themselves or their servants.

If an accident occurs attended with fatal consequences, a Coroner's jury inquires into it in England and Ireland; and if any accident occurs in Scotland, the Procurator-Fiscal inquires into it, and the Director, or officers of the Company would be held responsible, and be liable to criminal prosecution and punishment, in the event of culpable mismanagement being proved. If Parliament were to enact a particular mode of working, and if an accident were to occur under that mode of working, the responsibility of the manager would to that extent be diminished; and Parliament would probably be called upon to enact some farther detail of working to meet the newly-discovered danger. Several different systems of telegraphic working are in use, and Parliament is not a proper tribunal to decide which of these systems should be adopted.

Besides, a railway is so complicated an instrument, that whatever be the mode of working adopted, it would require modification under special circumstances. To meet objections of this nature against legislation by Parliament upon such details, it has been frequently urged, that a department of the Government should have power to regulate the mode of working to be adopted by Railway Companies.

The majority of accidents are due to combined causes; and, as much to a lax enforcement of good regulations, or to a neglect in using appliances for safety which are in existence, as to the absence of regulations, or appliances for safety. When accidents occur from an absence of regulations, or a want of the necessary appliances for safety, it frequently appears that such absence is due to the circumstances of the traffic having been altered, and to elements of danger having been gradually developed, without anything having occurred to bring the altered circumstances to the notice of the manager. Government interference would not necessarily meet this case. It is, moreover, the tendency of Government Inspection to seek to multiply accessories to safety; these accessories are more, or less valuable, according to the condition of the traffic on a line, and the manner in which it is worked. So long, therefore, as those who control the traffic are free to accept, or to reject the Government recommendations, it is very desirable that they should be made. But the more such appliances are multiplied, the greater are the chances of danger from their neglect, or their failure to act; and the chances of danger are diminished, or increased, according to the class and character of the men who use them. The selection of the men must always rest with the manager; and he should, therefore, remain responsible for the selection of the appliances for safety which he places in their hands.

It has been urged by Mr. George Robert Stephenson, (M. Inst. C.E.) that the Government should limit the speed of trains.[1] Had a rate of speed been prescribed by Government in the days of George Stephenson, probably the present rate would not exceed 20 miles per hour. The road and the machinery now in use render a speed of 40 miles per hour safer than the roads and machinery of those early days were with a rate of travelling of 15 miles per hour. But it would be as unwise to fetter speed now, as it was then; for mechanical appliances are, at present, as much below perfection, as they were in that day below their present degree of improvement. The fact is, that the safety of the traffic does not depend so much upon the system, as upon the individuals who administer that system. It would be better to have a faulty system, administered by good men, than a good system administered by careless men. These considerations lead to the conclusion, that freedom from railway accidents is not to be obtained by Government interference; but that it is to be guaranteed only by an effective and responsible internal management, which would enforce the greatest care and punctuality in working the traffic, and maintain the strictest discipline amongst the servants employed. Such improvements must originate with the Railway Companies themselves; and it is worthy of consideration whether some arrangement could not be advantageously made, for promoting safety and good management, analogous, in its nature, to the Association for the Prevention of Boiler Explosions, which has worked so successfully amongst manufacturers in the neighbourhood of Manchester.

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[1] *Vide* "High Speeds." A letter to the Right Hon. T. M. Gibson, M.P. By George Robert Stephenson. 8vo. London, 1861.

That Association was formed a few years ago, chiefly by the exertions of Mr. William Fairbairn, F.R.S. (M. Inst. C.E.), in consequence of the numerous boiler explosions which occurred when steam engines began to be worked expansively. The Association is entirely voluntary. It provides for the periodical inspection of the boilers of those persons who join it. The Reports show, that it has fully answered the expectations of its promoters, by preventing accidents in numerous instances, and it has rendered unnecessary any attempt at Government interference. The Association has moreover collated for reference much valuable information on the subject of boiler explosions.

It has been shown, that by the existing law Railway Companies are responsible for the safe working of their lines; and that if, in case of accident, culpable mismanagement can be fixed upon any of the superior officers, they would be liable to criminal prosecution. In practice, however, the complicated nature of railway management renders it, as a rule, impossible to fix such an amount of blame on any one of the superior officers as would justly render him liable to criminal punishment. Compensation, however, has to be paid by Railway Companies for accidents, the amount of which is sometimes enormous; but its operation as a penalty is uncertain and frequently unjust. It is, of course, impossible to say what number of accidents it may have been instrumental in preventing; but so long as the number of preventible accidents continues so large as it has been shown to be, compensation cannot be considered to have attained that complete success, as a means of prevention, which would be desirable. The law is, that if any person be injured, or killed, by the negligent act of the Railway Companies, or their servants, the person, if injured, or his representatives, if killed, are entitled to be compensated. The payment consequently depends upon the quality of the person who happened to be travelling in the train, or if killed, upon the description and number of his relatives, and upon the pecuniary loss they have sustained from his death: and it does not follow the degree of faultiness in the Company's arrangements. Thus, in the case of a collision on one of the Northern lines, in which the Report of the Inspecting Officer seriously inculpated the management of the Company, the amount of compensation paid was under £60; whilst on the Great Northern Railway the fracture of a tyre made of the best iron, procured from one of the most eminent manufacturers in the country, and which, till fractured, presented no outward sign of defect, cost the Company £1,260 for compensation, besides the injury to the rolling stock. In the case of a fracture of a crank-axle, procured from one of the best makers, which had only been run for a short period, and which had been carefully examined a short time previously, the Company had to pay £2,250 as compensation for injuries.

Considerable hardship is also frequently entailed upon Railway Companies when the accident has been occasioned by a simple act of negligence of one of the inferior servants. In one instance, when a collision occurred between a train and the fixed buffers in a terminal station, in consequence of the guard of the train having omitted to put on the break, on descending an incline into the station, the Company had to pay nearly £9,000 for compensation, in addition to £1,300 for law expenses, besides the repair of the rolling stock. In the case of the accident at Hitchin, which has been already alluded to as having been occasioned solely by the mistake of the signalman, the amount of compensation paid was about £11,500, and a sum of £1,650 was paid for law expenses, besides nearly £300 for damage to the rolling stock.

The most serious evil from which Railway Companies suffer, lies in the exaggerated and unfounded claims made upon them. As, for instance, on the North Eastern Railway, when on one occasion a person claimed £500 and accepted £35; while on another a person claimed £300, and accepted £20. These are fortunate specimens; such cases are rarely settled so easily, especially when recourse is had to a jury. In the following cases the Railway Companies have had cause to complain of the decisions of juries. In one fatal case it was proved, upon highly creditable medical testimony, that the deceased was a man of irregular habits, and that he was in such a diseased condition, that his life was not worth a week's purchase; yet the jury awarded nearly £1,100 damages. In another case a plaintiff obtained nearly £300 damages for an alleged injury to his wife's eye, although it was shown that the defect in her eye had existed long previously. Juries are not infallible. They are liable to the human infirmity of being led by their feelings; but it cannot be said, that they are a less fit tribunal for assessing damages in the case of railway accidents, than in other cases in which damages have to be ascertained; and probably, on the whole, a jury is a more satisfactory tribunal than a permanent judge. Railway Companies have, however, paid many claims, which they have considered fraudulent, to avoid the additional legal expenses, which recourse to a jury is almost certain to entail.

The present state of the law gives great facilities for fraudulent claims. A low class of legal and medical practitioners seek out claimants, and, relying on the sympathy of juries, make most excessive demands. The following quotation from the summing up of Mr. Justice Williams, on the 6th August, 1861, in the case of Clements versus the London and North-Western Railway Company, bears upon this question, and shows how largely legal expenses are increased thereby:—

> "It is not to be tolerated, that the occurrence of a railway accident should render the Company a prey to false and exaggerated claims, as the means of putting unnecessary costs into the pockets of the professional advisers of the claimants. It is manifest, if such a state of things were allowed to prevail, not only would fraud and injustice be triumphant, but in the result the ultimate sufferers would be the public, because it is plain that the fares which the public have to pay upon railways must be high enough to allow of a remuneration to the shareholders; and it is quite manifest that among those expenses must be reckoned the damages and the costs recovered in these law-suits; and the fact, therefore, is, that these damages and costs fall upon the public, to a certain extent, by reason of the necessity they superinduce for the Companies keeping up their fares."
>
> "Gentlemen, the inquiry has lasted a very long time, and a vast expense has been incurred in the trial of it. On the one hand, the plaintiff has called a vast number of witnesses, and it is impossible not to see that it is a very pleasant sort of case for the plaintiff; because, whatever the expenses are, he must be reimbursed his costs in this action. It is manifest the Company must bring a strong body of witnesses. It is manifest the plaintiff, also, is under the necessity of making his case as strong as he can; and as to the Railway Company, it will be unfair to consider as confined to this single case their resistance to what they think an excessive claim."

The offer of compensation by the Company is frequently taken as an admission of culpability, and it is used as a means of extorting a further amount. The following quotation from Mr. Baron Wilde's summing up in the case of Appleby versus the London and North-Western Railway Company, on 21st August, 1861, puts the evils of this grievance in very forcible language:—

> "If a Railway Company, having been the cause of an accident, have behaved liberally, fairly, and properly to the person who has been the subject of the accident, I think that an accident ought not to be turned into a method of pecuniary gain, and that the Company, if they really have dealt fairly and liberally with the question, ought to be protected in what they have done; and it is really of importance that that should be so, because if, notwithstanding the attempts of a Company to settle the matter, notwithstanding their making a liberal and proper payment, plaintiffs will always, acting upon a supposition that the jury when

they come to discuss the case will take the defendant's sum as a *minimum* and will always give the plaintiff something more, it will lead to every one of these cases coming into court. It leads to law in every case. It renders settlement impossible, and leaves no other alternative to the Company except to dispute the matter, from first to last—to dispute the negligence and the whole matter, at a very great waste of money both to themselves and to the person who is injured; and that system, when it comes to be applied to plaintiffs in poor circumstances of life, if you reflect on it, would be a very great injury. It would be a very sad thing if Railway Companies should be discouraged from making a fair and liberal offer and from paying the money to the plaintiff, if he will have it, or from paying it into court; because, as I said before, it will put many a man who can ill afford it to the necessity of an action."

Under existing circumstances persons who have been in an accident, but were unhurt, may attribute to it injuries otherwise received, and persons can, after any lapse of time, say they were in a railway accident, and unless the statement can be disputed, may recover damages; and instances have occurred of claims being made by persons who were not in the accident at all.

In considering these grievances, it is necessary to recal to mind, how the law of compensation has arisen. It seems to have been one of the oldest principles of justice, that an injury done by one man to another should be expiated by the infliction of a similar injury on the offender—thus 'an eye for an eye, &c.' Among savage tribes, including, until within a not very remote period, clans, or tribes among the Highlanders and the Irish, the "rough justice of revenge" (as Bacon calls it) prevailed; and it still does among uncivilized nations. By degrees the severity of the law was mitigated, and the offender was permitted to purge his offence by making compensation to the injured person, or when he had been killed, to his nearest relatives. Thus in the Anglo-Saxon laws of Ina and Alfred, compensation for injuries to men was provided for by minute assessments; the object was most humane, and the relatives of a slain man were entitled to compensation for his being killed. In process of time the remedy of the relatives for that sort of compensation was lost, but it was not taken away by direct legislation. Lord Campbell's Act was the Parliamentary recognition of that principle, and it was consistent with legal principles. It removed a technical difficulty in the way of recovering compensation that ought to be made, rather than gave a new right to the compensation. It is an advantage that in thus giving compensation to the injured party, the money payment operates as a punishment, and thus tends to prevent the commission of future careless acts. Compensation for a railway accident may, therefore, be looked upon, partly as a penalty on a Railway Company for its corporate carelessness, and partly as a compensation to the sufferer for the injury he has received. It would be difficult to substitute criminal punishment instead of the pecuniary compensation, because in most cases of railway accidents which have been occasioned by mismanagement, the contributing causes have been such as to render it impossible to fix such an amount of blame on any one director or officer as would justify a conviction in a court of law. If viewed as a penalty, it should be such as would tend to prevent a recurrence of the act for which punishment is awarded. It should, therefore, depend on the degree of blame which attaches to the management for the accident, and it should be equally certain and just in its operation. In its aspect as a remuneration, it should be easily recoverable by the sufferer. As at present levied, it does not properly fulfil these conditions.

In its operation on the Railway Company it depends upon the condition in life of the travellers; and has been shown not to be proportionate to the degree of blameableness of the Company. The liability to heavy compensation gives the manager a hold over the purse of the Company, which he would in some cases not otherwise possess; and this is a reason for retaining this penalty. But if it is to act systematically, or be a benefit to the public, it must act with justice to the Railway Companies. It is urged, by the latter, as a matter of injustice towards them, that whilst they are compelled, by Act of Parliament, to carry all persons who offer themselves, under similar circumstances, at equal fares, they have no power to protect themselves against the chances of heavy compensation to which the dissimilar circumstances of the travellers expose them. Thus, for instance, a labourer earning nine shillings a week, and a professional man earning £10,000 a year, both having families, may take similar tickets, say at one penny per mile, and if they are killed, the death of the first would cost the Company probably £20, whereas for the death of the second, they might have to pay £20,000. It would therefore seem to be equitable, so far as the Railway Companies are concerned, that the penalty should be limited in amount, and that the limit should vary with the class of carriage in which the persons conveyed were travelling.

In its aspect as a remedy to the sufferer, the present law gives rise to litigation; which frequently swallows up all the money paid by the Railway Company, and thus it is a heavy burden on the sufferer; and this litigation is urged as a grievance by the Railway Companies themselves. The litigation is to a great extent due to the fact, that the amount of compensation is unlimited. A liberal offer made by a Railway Company is frequently taken as a basis for litigation. The Railway Company consequently contends every point. The negligence has to be proved by a number of professional witnesses; their evidence has to be rebutted by an equal number on the other side: the amount of injury done has similarly to be proved on one side and disproved on the other by professional men; the expenses have amounted in many instances to several thousands of pounds. The taxed costs which the sufferer, if successful in his suit, would receive, would not cover legal expenses of this nature. The inducement to litigation would be diminished, if the amount recoverable as compensation were limited; and the grievances of which the Railway Companies complain would be diminished, if the compensation were recoverable, confined within a maximum amount which should be fixed with reference to the class of carriage in which the passenger was travelling. As part of such an arrangement any person desirous of obtaining larger compensation in case of accident, might have the option of insuring their lives.

In the Merchant Shipping Act, Parliament has recognised the principle of limiting the compensation, and of providing for it in an exceptional manner. By that Act the liability of shipowners is limited to the value of the ship and freight for the voyage; a minimum value of £15 per ton being placed on the ship.

The other side of the question must not, however, be forgotten. A limited compensation means that in some cases the sufferer would not receive an equal amount to that which he would receive under the present law; whilst even now it does not always happen that the money payment really compensates the sufferer, for it is obvious that no person would willingly become crippled for life for a money compensation.

Although the whole amount of compensation, including the heavy fines occasionally paid, when spread over the whole number of travellers, amounts to a very small sum per passenger per mile, the liability to unlimited compensation is a strong inducement to the railway directors to cause the employés to work the line carefully. Whilst giving full credit, however, to the effect of compensation, it must be noticed, that the personal feelings, convenience, and interests of the managers influence them in the strongest manner, to avoid accidents; and the fact that an accident was attributable to mismanagement would be quite as galling to the employés of the Company, if nothing had to be paid, as if it involved enormous compensation.

It has been shown that the present law does not insure that care in working which is necessary. The object of an alteration ought to be, to devise a system which would insure that such care would be taken as the public safety demands; and that the grievances, of which Railway Companies now complain, should at the same time be remedied. How far would the limitation of the amount payable as compensation tend to such a system? Assuming that the compensation was fixed at such a maximum amount as would fairly compensate the generality of passengers, according to the class of carriage in which they were travelling;

and assuming that it were made payable in the case of every accident which occurred, beyond the control of the passengers, without there being any obligation to prove negligence, there is reason to believe, that the fine would be rendered more certain in its operation, but that as a preventive, the effect of the alteration would not be appreciable. The personal interests of the managers, to prevent accidents, would however, remain; and such an alteration would tend to diminish the grievances of the Railway Companies; whilst it would also benefit the community at large, by diminishing litigation.

The true remedy against railway accidents lies with the Railway Companies themselves. Improved management would be greatly assisted by placing at the head of each railway a Director of adequate capacity, responsible to the Board for the management of the concern, who should be required to devote his whole thoughts to its interests, and be paid in proportion;—by giving the chief officers of the railway control of and making them responsible for the several departments, so that they might be held answerable for results;—and by providing a gradation of responsibility throughout all the employés. Improvements in the machinery and system of working would be promoted by the formation of an Association amongst Railway Companies, combining the objects of the Association before mentioned, between the German Railway Companies, and of the Association between manufacturers, near Manchester, for the prevention of boiler explosions. It is doubtful, however, whether such an arrangement would be of any practical utility in this country, unless it assumed the form of a combination among the Railway Companies for the purposes of mutual insurance against railway accidents, to which all the lines should contribute, and in which they should all be represented; and it should be managed by a Board of railway men chosen from the Associated Companies. If such an arrangement could be adopted, it would obviously become the right of the Association, as well as its duty in the interests of the insurers, — the individual Railway Companies,—to examine into the detailed working of the several lines, to inquire into the accidents which occurred, to point out defects and to compel a carelessly-managed railway to improve its management, under penalty of being excluded from the benefit of the insurance in case of accident. Such an arrangement would diminish the inducement which the liability to a money payment gives a Company to manage its line properly; but it may be a question whether this would not be fully compensated for, by the influence the Association would have over the management generally.

The Author has thus endeavoured to lay before the Members the general considerations which bear upon this very complicated question. He fears that this has been done in a manner very inadequate to the importance of the subject; but he trusts that his Paper, by affording an opportunity for a full discussion of the question, will be a means of promoting the interests of Railway Companies and of the public.

Professor AIRY exhibited a model of an apparatus which he had designed for the purpose of effecting a communication between the guard and the engine driver. He stated, that the connection was effected by means of a clutch which, although of peculiar construction, was simple and inexpensive. It was composed of two forked pieces of similar shape, but which were disposed at right angles to each other. The peculiarity consisted in its capability of being turned through a considerable angle, and yet if driven endways it was sure to take hold. It might also be raised, or depressed, or be moved laterally, and still, when driven in, it would be secure; indeed, it might be moved in any way, and yet, if pushed forward, would retain, within certain limits, the same amount of hold. By this means an effective connection was attained between any two successive spindles. In applying the apparatus, he proposed, that each carriage should be furnished with a spindle extending from one end of it to the other. The tender was to be furnished with one part of the clutch, and each of the carriages with a similar part at each end. At one end, the fork was to be in a vertical position; and, at the other, in a horizontal position. The great advantages of this apparatus were, that it would be always in readiness, so that no preparation would be required when starting a train, that it would not be liable to get out of order, and that from its not requiring good workmanship it would be inexpensive. As a collateral application of the apparatus, he would notice, that by fitting auxiliary machinery to the spindles, a break might be put upon every wheel of a train.

Captain TYLER, R.E., remarked, that porters were frequently crushed between the buffers of railway carriages. He would inquire whether Professor Airy had made any provision to prevent them from being caught and injured by the proposed clutches?

Professor AIRY replied, that his ideas on the subject had not gone to a greater extent than he had already stated.

Mr. SIEMENS said, the comparative safety of the German and other Continental railways was principally owing to the smaller number of trains which were run, and the lower speed at which they travelled. The interference with the personal liberty of the passengers, which formed part of the Continental system, would not, however, suit English habits and notions, and the custom of locking up the passengers could not be considered an element of safety. Passengers were seldom, if ever, injured on a railway platform; it was while the train was in motion that the principal danger existed. The careful manner in which the rolling stock was manufactured on the German railways also contributed to their safety. Through the agency of Mr. Krupp, cast steel had been very successfully employed in the manufacture of tyres and axles.

He believed that gentleman alone had supplied nearly fifty thousand of each, and he had been followed by other manufacturers. In fact, at the present time it was exceptional to find anything but cast steel tyres, or axles on the German railways. Much depended upon the manner in which the tyres and axles were prepared. Mr. Krupp had devoted much time and attention to the subject. The hammer which he employed weighed as much as 45 tons, and fell through a space of 10 feet. The anvil was composed of nine pieces, and weighed nearly 1,300 tons. The centre piece was a solid casting, weighing 185 tons. It rested upon the remaining eight pieces, which were of a segmental shape, and each weighed 135 tons. It was only by means of such an agency, that large masses of steel could be welded, so as to form a compact and homogeneous mass. The steel tyres and axles so prepared were used on the northern railways in Germany, where the winter was very severe, and Mr. Siemens was not acquainted with a single instance of a tyre, or an axle breaking during frost.

Another point in regard to the management of the railways in Germany deserved attention. The arrival or passage of each train was telegraphed from station to station, and two trains were not allowed to occupy one section of a line at the same time. He thought, that sufficient consideration had not been given to the advantages which would be derived from the adoption of a similar system in England. The trains on the main lines of this country followed each other, in some cases, at as small an interval as five minutes. It would be more correct not to divide the space between them by time, but by distance. But, assuming that a system of telegraphing the train was adopted, as five minutes would represent a distance of 2 miles, or 3 miles, there would be no difficulty in signalling trains at such intervals. If the stations were further apart than 2 miles, or 3 miles, special telegraphic stations might be provided. The mode of signalling adopted in Germany, was to announce a train, at the moment of starting, to the next station, by large bells, placed at intervals of about half an English mile, so that all persons on the line heard when a train had left station A, on its way to station B. Platelayers and switchmen engaged on the line could calculate, within a few seconds, when the train would pass them. The moment the train arrived at station B, the signal was sent back to station A, that the line was clear, and the general signal was conveyed to station C, and so on along the line. Perhaps such a system of announcing a train all over the line, would not meet with the approval of English railway engineers; but he thought a system of signalling trains from station to station, and a rule that two trains should never occupy the same section of line together, could be readily introduced without any inconvenience, and he believed, it would effect great saving of time in the working of the lines.

The arrangement adopted upon several of the German railways was shown by the apparatus he had placed on the table. Small bells were fixed at the stations, and such intermediate points as were thought necessary, and at the moment of leaving, the guard, or other person in charge of the train, turned the handle of the magnetic indicator, which announced at every signalling point, that the train had started. Any number of such bells might be rung at the intermediate points. By this signal the train obtained possession of a section of the line, and no other train was allowed to enter that section, until station B had, by another signal, notified that the train had reached it. It was obvious, that such a system might be varied to suit any particular case.

Mr. BABBAGE remarked that railway accidents might be divided into two classes; first, those accidents which arose from human agency; secondly, those which were the result of mechanical causes. As regarded the latter class, in consequence of the great difficulty in ascertaining the exact mechanical facts in respect to any given accident, it was very desirable that machinery should be employed to measure and to record them. In 1839 he made some examinations in reference to the Great Western and other railways, in the course of which the Great Western Railway placed at his disposal a second-class carriage and afforded him all necessary facilities for carrying out his experiments. The inside of the second-class carriage was cleared out and it was fitted up in the following manner:—Holes were made in its bottom, and through these strong wooden supports were firmly fixed on the framework to which the wheels were attached. On the supports a table was fixed which extended the whole length of the body of the carriage. Large rollers were attached to each end of this table, on one of which was wound a sheet of paper 1,000 feet in length. The rollers, being connected by a chain with the axis of one pair of the wheels of the carriage, were caused to revolve, and the paper to pass along the table, at any desired rate from 3 feet per mile, to 40 feet per mile, for each mile passed over by the carriage. In the middle of the table, and just above the paper, a small platform supported nine pens, which, by means of various mechanical contrivances, were moved transversely across the paper, to and fro, according to the deviations from the mean which the various causes indicated. The first of these pens, was to indicate the velocity of the carriage at every instant during its journey. For this purpose the pen was connected with a chronometer movement, beating seconds. This caused a dot on the paper at each second during the journey, and from the number of dots in a given space, the velocity could be ascertained. At the commencement of these experiments the chronometer was broken several times, so that at last he was obliged to remove it from the table, and to suspend it on the springs, having contrived means of communicating its movement. The second pen was connected with a powerful spring by which the experimental carriage was attached to the engine. This pen, by its deviations above a horizontal line on the paper, expressed the force of traction which the engine exerted on the experimental carriage, and on any others that might be attached to it. It was called the curve of traction. The third pen was destined to record what he called the 'curve of progression.' It was well known to most persons who had paid attention to the peculiar motions of a railroad train, that, on looking out of the window of any carriage in a long train it frequently happened, that the rest of the train appears to have a continuous serpentine movement. In that case the wheels of each carriage successively approached one rail, until the rims of the wheels are repelled by the edge of that rail, and then they in like manner approached the opposite rail. This serpentine motion was injurious to the rails as well as to the carriages, and was a source of expense to the Railway Companies and of danger to the public. In order to have an accurate register of its occurrence, a piece of 'quartering,' 3 inches by 3 inches in section, was suspended to the carriage by a powerful hinge joint. To the end of this, was fixed a piece of iron, having a projecting wedge of steel. The wooden arm thus constructed, was pressed by a strong spring against the rail. The motion, arising from this steel projection pressing against the side of the rail, was conveyed by proper mechanism to the pen, which thus indicated the serpentine movement of the train. This apparatus was exposed to great and irregular forces, and was often broken four, or five times, during the day's work. As it was liable, from its position, to become a source of danger to the carriage he took special precautions about it, in accordance with a principle on which he had constantly acted on similar occasions. The principle he alluded to was:—Whenever any portion of a machine is liable if broken to become a source of danger, it ought always to be so contrived, that it shall break in that part which will cause the least danger. The part broken off should also be immediately withdrawn. In pursuance of this principle, the wood was strengthened longitudinally by hoop iron, except at one part, for about the space of an inch, where a small notch was cut in the wood, to direct its point of fracture. The lower portion of the wood, to which the steel point of pressure was attached, was connected by an eye with an iron chain, so placed, that if the apparatus broke, the fragment could be immediately withdrawn from the rail. The disconnection of its pen warned the experimenters in the carriage, and by means of a rope, attached to the short chain, the fragment was immediately drawn up close to the bottom of the carriage. The other six pens related to the body of the carriage. Three of the pens were employed to draw curves expressing; First, the vertical shake, or rise and fall of the body of the carriage at its centre; secondly, the lateral shake at the same point; thirdly, the end shake at the same point. The other three pens indicated the same actions, as they occurred at one of the extreme ends of the body of the carriage. Mr. B. Herschel Babbage made all the drawings of the machinery and of the carriage employed, and assisted Mr. Babbage in all the experiments. The machinery itself was extemporised, and was executed in haste: it however answered its purpose, and ten sheets of paper, each 1,000 feet long, were wholly covered on one side, and partially on the other, by the curves, thus traced and mechanically recorded. It would occur to those acquainted with the subject, that at the present time, such a machine might be greatly simplified. He had on another occasion reduced the length of paper required, to a very small fraction of that which was then employed, by covering a revolving cylinder with one layer of paper, and by causing it to advance endways by a screw. By that means a long spiral was described by the pen, which pressing against the paper, recorded the variations of its position. Some time since, he used the same principle for a little instrument intended to record the beating of the human pulse. He had observed, that by placing his wrist in a certain position, he could see the pulsations more distinctly by means of their shadow, and had devised an instrument which recorded by photography, upon paper, any series of such pulsations. In conclusion, Mr. Babbage said, that without proposing that the special apparatus he had described should be used, he considered, that every engine ought to record by machinery, and upon materials beyond the control of the driver, the following particulars:—First, the times of starting and stopping; secondly, the velocity at every instant; thirdly, the tractive force employed; fourthly, the curve of progression. Such facts would be invaluable for detecting the mechanical causes of accidents, and they would also afford a very great check against those which might arise from negligence.

Sir JOSEPH PAXTON did not think that the results which had been given in the first Paper correctly represented the facts connected with accidents on railways. No doubt they had been compiled from the best data that, under the circumstances, could be procured. The proportion of 76 per cent. attributed to faults of management appeared to him to be excessive, and it certainly did not agree with the results which had fallen under his observation, on railways with which he was connected. He had for many years been Chairman of the Committee of Ways and Works on the Midland Railway, and had paid special attention to the manner in which the fish-joints were acted upon, by passing trains, and his experience led him to prefer, that the fish-joints should be placed in the ordinary manner between the sleepers. When so placed, they regulated the action of the rails, and enabled them better to sustain the passing weight. He did not think that any advantage would be gained by adopting the suggestion, that two whistles, having different tones, should be used by engine drivers; on the contrary, he considered they would perplex the railway servants and be a source of alarm to the passengers. It would be a retrograde movement to adopt lighter engines; the tendency of the present day, was to increase the weight of the engines and the capacity of the carrying stock. In this country the weight of engines had increased from 10 tons, to 30 tons, or 40 tons; but on the Great Northern Railway of France, engines were in use which weighed as much as 60 tons. Some of those engines were placed upon eight wheels, by which their weight was proportionably distributed, and the admirable manner in which the permanent way was maintained on that railway, showed that those large engines had not injured it. Instead of trucks carrying 5 tons, waggons carrying 10 tons were now in common use, and he thought this progressive change was in the right direction. All acquainted with the subject were aware, that at great velocities, light carriages swung about more, and were more subject to accidents than heavy ones, and that the latter were not so easily thrown off the rails. Continuous breaks were no doubt very well in theory, and possibly might be used on short lines of railway; but in the commercial view of the question, were inapplicable on longer and larger lines, where the traffic was great and the junctions were numerous.

As regarded the class of railway servants at present employed, he did not think any benefit would result from the establishment of a higher rate of wages, or the employment of a better-educated class of men. He would, in illustration, take the case of a pointsman. A man in that position spent a large proportion of his time in solitude. If educated, he would endeavour to employ his mind in some manner, such as reading the cheap periodicals, which would withdraw his attention from his work, whereas an uneducated man would in all probability have his attention fixed upon his duty solely. Again, it was well known, that the best stokers and engine drivers were not those which had been taken from the fitters in the workshop—men who were educated, and had a mechanical turn of mind—but those who had been brought up in the mode now generally adopted on English railways. A sharp active man was employed for two years as engine cleaner, and from that position he gradually progressed until, in the course of three or four years, he became an engine driver, and the practical knowledge, thus acquired, was the occasion of his superiority to a man who had been brought up in a workshop. He concurred in the remark, that freedom from railway accidents was not to be attained by Government interference.

Mr. SEYMOUR CLARKE, in answer to the President, remarked, that the first Paper would have possessed novelty had it been written twenty years ago, but, at the present period, he did not think any benefit would arise from discussing the suggestions which it contained.

Mr. BIDDER (Past President) could not concur in the opinion, that railways would be better managed if undertaken by Directors who possessed the time, and the opportunity, to devote their attention to details. He had been connected with the construction and management of railways for many years, and had very early experience of the effects of minute directorial interference, and from that period, up to the present time, his experience had been most unfavourable to it. Considering the way in which railway directors were for the most part elected; that the qualifications for the office were not always measured by ability to discharge the required duties, and also that a director was more or less an irresponsible officer, it must be obvious that no advantage could be derived from such a change. When directors did interfere, it was often on points of minor interest. In one case which came within his own knowledge, a young director thought, that he had an opportunity of showing how much he could effect in the way of economy. In travelling upon the line, it occurred to him that there was a great deal of gas wasted at the stations. He got special permission from the board to take the expenditure of gas under his consideration, and an officer was specially appointed and paid to see that the gas was turned down to the lowest point at the station the moment a train left, so that the next express train generally put all the gas out. At the end of a month, it was found that at one station 100 feet of gas per week, of the value of about sixpence, had been saved! Directors were, in general, unaccustomed to the management of large masses of men, and therefore the special duty of the board was to select proper officers, but not in any way to interfere between the officers and the men under their control. When officers failed in their duty, the board should dismiss them. Whenever the directors interfered with an officer in the actual discharge of his duties, mischief ensued.

He would not enter into the details of the question, how railway accidents might be diminished; nor would he attempt to account for the greater number of accidents in England, as compared with those on the Continent, beyond noticing that, in all other respects English habits were different from those of Continental nations. It might be said that in this country the railways were made for the public: whereas on the Continent, although the public might not be made for the railways, yet the travellers were made subservient to the railways. English Railway Companies were, in consequence, obliged to maintain a speed of travelling very much beyond that which prevailed on the Continent. He believed, that these causes alone were sufficient to account for the discrepancy between the relative proportion of the accidents in this country, and of those on the Continent.

No doubt, continuous breaks—if generally brought into use, but that would be very difficult of attainment, for the reasons pointed out by Sir Joseph Paxton—or any means by which power could be intensified, would obviate a certain class of accidents; but as it had been found, that such a system would create another class of accidents, there was no reason to suppose, that the total number of accidents would be materially reduced. He would go further and say, that it was owing to occasional accidents, that greater vigilance was induced to prevent the recurrence of others. If by the interposition of some miraculous power, accidents could be prevented for the next four years, or five years, it would probably induce such an amount of negligence and inattention, as would speedily make up for any previous decrease in the average number of casualties.

With regard to the actual state of the law in respect to railway accidents.—It was generally acknowledged that the provisions of Lord Campbell's Act had not operated beneficially for any interest, suggestions should therefore be made with a view to its modification. To illustrate the effect of the present state of the law on the subject, he would instance some of the facts which had transpired, and their results as applicable to the public and to the railways: and he would confine his remarks to cases within his own experience. In the first place, the principle must be admitted, that the law ought to operate so as to secure to the sufferer ample indemnity, with as little expense as possible to himself and to the Railway Company interested. Now he believed, that the present law operated in the opposite manner. One case in which he was concerned occurred on the Great Northern Railway. A portion of the line was subjected to a sudden inundation. An express train was precipitated into the water, and disastrous results ensued. The consequence was, of course, an inspection by some of the officers of the Board of Trade, and that was followed by reports which set acute lawyers to work. They brought action upon action, and made a combination amongst the plaintiffs. The result however was, that by extraordinary exertions on the part of the Company, the plaintiffs were defeated in all the suits. The Company paid nothing as compensation to the sufferers, although they expended thousands of pounds in the course of the litigation. On the other hand, he believed that the result was almost utter ruin to some of the plaintiffs. Such was the consequence of litigation in the existing state of the law.

The next case was the accident, on the same line, at Hatfield: there Mr. Pym happened to be killed, and the jury found a verdict against the Company. Mr. Pym, at the time of his death, had a life interest in a large estate. If he had died suddenly by other means, his family would have been left dependent upon what the eldest son thought proper to allow them; but, having been killed upon the railway—Mr. Bidder would not enter upon the question whether the verdict was right or wrong—the eldest son became pecuniarily benefited by the fact, that the death of the father was occasioned by a railway accident; and that contribution which, under other circumstances, he ought to have made towards the maintenance of his mother and sisters, was forced upon the Railway Company. Now as to an accident, which occurred on the Eastern Counties line at Tottenham, in reference to which two actions were brought. By the verdict in the first action, the Company were compelled to pay damages, together with their own expenses, and the taxed costs of the plaintiff. In the next action the Company were successful: they had no damages to pay, and he presumed, as was usual, the plaintiff had to pay the taxed costs of the Company. What was the result? The Company was heavily mulcted; and as between the two plaintiffs, he undertook to say, that the amount awarded to the one plaintiff was consumed by the costs of the two. The practical result of the two actions being, that if the two plaintiffs were taken jointly they got nothing; that the Railway Company was heavily mulcted; and that, in substance, the only persons who really benefited were the legal gentlemen employed. Now how did such a result arise? A Railway Company could scarcely get justice in a court of law. Under the most favourable circumstances, the chances were almost nine to one, that the jury gave a verdict against the Railway Company, and in favour of individuals. There was another matter peculiarly unfavourable to the railway interest. The Board of Trade deputed one of their inspectors to go and investigate the circumstances of any railway accident which occurred. The officials of the railway received him courteously, and everything was exposed to his observation. Such a course on the part of the railway officials would be quite right upon one presumption, namely, that the gentleman went there with a judicial feeling, and with an anxious desire to do justice between the public and the Company; but he would appeal to past experience, as to whether that duty had been discharged impartially and calmly, as to whether those gentlemen had not been converted into partizans instead of judges, and as to whether, in their reports to the Board of Trade, they had not furnished acute solicitors with evidence and circumstances for bringing their actions. He had no hesitation in saying, that Railway Companies and officials had been extremely weak in the extent of their attention to these gentlemen. He advised them to say—"Here is the road: here are the carriages: go and look at them for yourself." Every admission the railway officials made was turned against them. And what followed at the trial? He, for instance, might be called on the one side, and another Engineer on the other: they were supposed to be more or less advocates. But those gentlemen were called; and they were asked, "You are an Inspector of the Board of Trade?" Introduced in this manner to a jury, who were utterly incapable of forming an opinion on scientific matters, the evidence of the officers of the Board of Trade had a weight attached to it, to which it was not intrinsically entitled, either from experience, or length of service. In almost all railway accidents, the accident itself obliterated the only correct evidence of its cause. All subsequent attempts to form a judgment on the subject, were more or less based on hypotheses, and depended upon scientific evidence, and that had to be weighed by men, to whom science was almost as unintelligible as Arabic, or any similar language. Unless a jury was composed of men who could weigh the effects of scientific evidence, it was a matter of chance what the verdict would be; that was, supposing the jury to be impartial; but it was notorious that an impartial jury could not be obtained in a trial between an individual and a Company. He would also sustain these remarks by reference to the accident which took place at Merton, on the South-Western Railway, and which made a great impression upon the public mind by the death of a gentleman of high promise—the late Dr. Baly. The accident occurred near the junction with the Leatherhead Railway. The engine never went off the line. The tender did, and fell between two embankments, and was broken to pieces. After that there were three or four carriages thrown off the line, and, amongst the rest, the guard's break, which was not next the tender, but at some intermediate part of the train. The guard's van was also off the line, but did not entirely clear it. It was incontestably proved, that the guard had his break on, assuming something was wrong. It was also proved, that the tender was not the origin of the accident, because the driver was on the point of putting on the break, on account of something being wrong with the train, when the tender was suddenly disconnected from the engine. The carriage in which Dr. Baly was, was not thrown over on the left-hand side of the rails, on which the train went over, but on the right-hand side, by coming in contact with the guard's van. Those were the principal circumstances which attended this accident. Now he had mentioned, that in all these accidents the cause was obliterated by the accident. He was called upon by the South-Western Company to give his opinion on the subject; and when he went to the place, it occurred to him, as to all who went, that the accident must have occurred from the tyre of the wheel of the tender shifting a few inches. Assuming that to be the case, every other act to complete that accident could be accounted for logically; and, therefore, if it had not been for other circumstances, he believed every one, both on the part of the Company, and on the part of the sufferer, would have been under the impression, that the accident was due to the shifting of this tyre. It was proved afterwards, that this tyre could not have shifted, and the point, with one exception, was entirely given up. This showed how unfair it was, that verdicts involving large amounts of money should be inflicted upon Companies, upon hypotheses based upon scientific evidence. It had so happened that he had been in a railway accident himself. Some of the gentlemen who had addressed the meeting evidently had not. If they had been, the rapidity with which it occurred, and the thorough loss of mind, in the instant between the initiation of an accident and its conclusion, would have impressed them with a very small appreciation of those ingenious devices, to which they attached so much importance.

Objections had been taken to the conduct of the South-Western Railway Company, because they would not adopt sundry official crotchets, and because they would not abandon certain plans which had been initiated on their line. Mr. Bidder would say, that a Company, in abandoning plans which had practically answered the purposes of a railway, and to which all their servants had become drilled, would incur a serious responsibility in adopting any other plan, however theoretically perfect the new plan might be. He, therefore, thought that the South-Western Railway Company acted rightly. It had been, however, said that, if continuous breaks had been used, the probability was that Dr. Baly's life would have been saved. He thought, that was an opinion which should not have been expressed. To say, that in a railway accident, what might have saved one life, might have involved the loss of many others, was a question of history. If there was any probability in respect to the cause of the accident, it was, that it was occasioned by the break van going over, and, that if the van had not been on the line, Dr. Baly might have been still alive; because, if the break van had gone a foot more off the line, the carriage, in which Dr. Baly was, would not have been thrown off the line.

It was here objected that Mr. Bidder was reasoning on incorrect data.

Mr. BIDDER continued—At all events, whether the data on which he made his statement were correct, or not, he would say this—that for any gentleman to say in a crash of that nature, that this, or that cause, might have saved life, he thought, was a great presumption indeed, and one which, with all his experience, he would not have ventured to enunciate. It had been, moreover, stated that that part of the line was irregular—that there was too much 'cant,' or super-elevation of the outer rail, in places, and it had been said before the jury, what Mr. Bidder was sure would not be repeated in that room, that if the train had been going faster, it might not have gone off the line at all. Now when Mr. Bidder saw the line on the Saturday after the accident, strange to say, the road had not been disturbed since the accident. It had been left in the same condition for several days, and all the ordinary traffic had passed over it. Now he need not say before practical men, that by the eye alone they could tell whether the line was in good order, and he stated in his evidence, that he would have gone over that, with as much confidence, as over any other piece of road. But the Government Inspector had said that the road was not in good order, that it had too much cant, that it was out of gauge (which did not matter, unless it was too narrow, because it was on a curve), that there was oscillation, and that had conduced to the accident; while, at the same time, he was unable to state what went off first, or to specify the exact super-elevation of the outer rail. As regarded the cant, it was unnecessary to point out, that it could not be always right. If it was wanted to be right a fortnight hence, it must be adjusted, so as to be a little in excess at the present time. With a gradient of only 1 in 264, the jury were told, and they believed, that although the accident occurred at a moderate speed, yet, if the speed had been greater, the accident might not have occurred at all. That was evidence which he was sure would not have been given before such an assembly as he had now the honour of addressing. But probably the Board of Trade Inspectors were not aware of the practical limits to the perfection of a railway. They might possibly think that a railway should be perfect. For the sake of illustration, he would assume such to be the case. Let it be imagined that the ocean, when perfectly smooth, was congealed into a bed of Krupp steel, and that out of that a straight railway was ground, and that upon it was placed the most perfect engine and train. It was a self-evident fact, that at a speed of forty miles per hour, that train would not keep on the line for 100 yards. A railway was like the British Constitution —a system of compromises. There was no such thing as a perfect railway. It could not be kept in perfect gauge, or perfect cant; it could not be perfectly level, nor perfectly rigid. It was a question of compromises; and those who were in the habit of dealing with these questions knew to what extent those compromises might go. The experience of Mr. Strapp, the Engineer of the South-Western Railway, should have had more weight than that of any Government Inspector, who had never had twenty-four hours' management of a railway. Mr. Bidder must say that he preferred his own judgment, after thirty years' experience in connection with railways, to that of any officer. He had seen the line, and he said most distinctly it was as fair a piece of permanent road, as he would desire to travel upon; and yet it was upon such evidence as that to which he had referred, that the Company had the verdict given against them. To such an extent had the system of prosecuting Railway Companies gone, that the judges before whom the causes should be heard were selected. There were some judges who were determined to impress upon the jury the real weight of the evidence. Those judges were avoided by the acute gentlemen who had the cases against the Railway Companies. Was that a state of things that ought to continue? He believed there were no men more anxious to remedy this state of things than the gentlemen of the bar. It was only the low sharp practitioners, whom the present law favoured, who were anxious to maintain it.

The question therefore came—in what practical way could this state of things be remedied, so as to conduce to the interests of the public, and operate advantageously, as regarded the railways? He contended, that the present system was unfair to the railways. The limitation of liability ought to be fixed as in the case of goods, except where the value was declared; and the amount payable on the death of individuals should be fixed according to class (without question as to the cause of the accident) at a moderate amount; and if any portion of the public wished to secure to themselves further compensation, they should declare their value, and pay a rate accordingly.

It might be objected, that the Companies would thus be released from the pecuniary results of accidents by a species of insurance fund; but to meet that objection, he would go so far as to place the insurance at half the risk, and to guarantee that the amount should be paid, without legal proceedings. He would further propose that the rate of compensation, which the passengers might elect to pay for, should be paid without question; that the fund should be managed by delegates from eight or nine of the large Companies; that on the board so composed there should be an *ex-officio* member appointed by the government; and that the losses should be distributed amongst the Railway Companies in proportion to their capital and revenue; also, that the board should have power to investigate all the circumstances of an accident, and to dictate to the offending Company, such regulations as the circumstances of the case pointed out. The result of such an arrangement would be, that as every Railway Company, in turn, might be subject to the inquisition of this board, it would not be likely that those gentlemen would be solely guided by theoretical ideas, but, on the contrary, they would investigate the circumstances with all the weight of responsibility upon them, knowing that they might be laying down a precedent for themselves, and that all they proposed would be of a strictly permanent nature. He could not help thinking, that some such plan would place a great deal more money in the hands of the sufferers from accidents, at much less cost to the Companies, and also be the means of introducing such real improvements in the working of railways, as would tend to reduce the number of accidents, and, that at the same time, it would work far better than any description of control exercised by a department of the Government. Railway Companies should be made liable for a given amount of compensation, under any circumstances. That was to say—it might be £100 for a first-class passenger, £75 for a second-class passenger, and £50 for a third-class passenger; and the amount so fixed should be paid, without question, on a fatal result occurring from any accident. There would then be no litigation; but the loss would be made good by a rate distributed over all the Railway Companies. That would justify the other provision which he proposed, namely, that the committee, so constituted, should have most complete and ample powers for investigating all the causes attending every accident, and that they should be empowered to dictate to any Company whose arrangements appeared defective, such corrections as appeared to them necessary. There could be no question, but that such a committee would possess a moral influence, which would reconcile the Companies to obeying their injunctions; for this reason—that they would be practically well-informed, and hence would not be likely to concur in unreasonable demands.

With respect to the remarks he had made as to the proceedings of Government inspectors in cases of accidents, he wished to be understood, that his objection was, that, instead of those gentlemen confining themselves to the narrating of facts, which came within their scope of inquiry, they committed themselves to opinions, and hypotheses, which militated against the railways. The recent trial, with reference to the explosion on the London and North-Western Railway, was an additional illustration of the correctness of his views, and he was sure, that all who had read what took place on that occasion, would concur in the propriety of his observations.

He begged to disclaim all intention of making any personal imputation as regarded the Inspectors of the Board of Trade. He believed the gentlemen appointed to those offices were men of the highest honour, and had no personal motives in what they did: his objection was to the manner in which they discharged their duties.

Colonel YOLLAND had been much surprised, when the assertion was made by Mr. Seymour Clarke, that the first Paper read contained nothing but what was known some twenty years ago, or would only have been new at that time. The Great Northern Railway Company, under that gentleman's able management, had, certainly, within the last few years, made great strides in reference to avoiding one particular class of accident pointed out in that Paper, namely, in the prevention of accidents to trains from the fracture of tyres, a class of accident which generally resulted in the whole, or a part of the train, being thrown off the rails. Not many years ago, the returns to the Board of Trade, from the Great Northern Railway Company, were very largely filled with accidents caused solely by the fractures of tyres. But he believed that in the year 1861, when so many of the neighbouring Railway Companies suffered severely from that class of accident, the Great Northern Railway Company was almost, if not entirely, exempt. In that respect, at least, the Paper alluded to, pointed out a great change for the better, as regarded the Great Northern Railway Company. With reference to the comparative advantages of the two different kinds of fish-joints, from all the information he could gain, he believed that there was no doubt but that the suspended fish-joint possessed great advantages over the bracketed fish-joint. Many of the Railway Companies which had tried both plans, had given up the bracketed, in favour of the suspended fish-joint.

He had taken some pains in going through the reports which had been made by the inspecting officers of the Board of Trade since he first joined the department, now rather more than seven and a half years ago. During that time, inquiries had been made in reference to 599 accidents. These he had analysed, in a somewhat different manner from that adopted in the tables before the Institution, for the purpose of drawing some practical deductions, which were not adverted to in the Papers which had been read. In making this analysis, he would refer more particularly to the accidents to trains, of which there were no less than 540, and would discard the 59 which related to accidents to persons. Of the 540 accidents to trains, 65·6 per cent. were collisions, representing 354 accidents; and 28·9 per cent., representing 156 accidents, were due, to trains getting off the line. These were the actual facts, and not deductions founded on opinions. Boiler explosions, fortunately, did not very much concern the general public, as the explosions seldom occurred except when the engines were standing still; but this class of accident killed and injured a considerable number of the Companies' servants, and these accidents contributed about 4·6 per cent., represented by 25 explosions. It would be gratifying to the members of the Institution to hear, that the accidents to trains arising from the breaking-down of bridges, did not amount to 1 per cent., the actual figures being 0·9 per cent., representing 5 accidents. These numbers made up a total of 540 accidents inquired into, during the years 1854 to 1861 inclusive, besides 59 others of a miscellaneous character—such as persons being run over, while crossing the line at stations, or level crossings, or being struck against works, &c. With respect to the 65·6 per cent., representing the collisions of one train with another, or with buffers at terminal stations, the greater proportion, if not the whole, might be prevented, if Railway Companies would take the necessary measures for that purpose. The proof of this assertion was furnished by the fact, that they did not occur at the most dangerous places. On every line, those were more particularly guarded, and the collisions which would otherwise have taken place, were in consequence avoided. Nor did they occur on the crowded parts of the main lines running out of London, owing to the special precautions taken against them.

Attention had been drawn to the fact, that collisions might be avoided by means of the greater use of the telegraph. It was quite certain, that if two trains were not allowed to run in the same direction, or in opposite directions on the same line, in the space between any two stations, or two telegraph huts, at one and the same time, it would be impossible that collisions could occur. But the adoption of an interval of time, as laid down in the books of regulations, was altogether illusory as a certain means of avoiding collisions. There might be a five minutes' interval, or a ten minutes' interval, or a twenty minutes' interval, between the departure of two trains from a station, and yet before the last train had reached its first stopping place, eighty miles distant, the interval of time might have entirely disappeared, and the leading train might be run into: whereas, if an interval of space, say of one mile, two miles, or three miles, were preserved, it was quite impossible that collisions could take place, except from running into a train which had been thrown off the rails, while travelling in an opposite direction, on the other line of railway.

He would now pass to the second class of accidents to which he had directed the attention of the meeting, namely, those occurring to trains from running off the line. It was quite true, that it was not always an easy matter to state, what was the cause, and what the effect, of a train getting off the line, but the Inspecting officers gave their opinions honestly and candidly, and his analysis was founded on their reports. Of course they were liable to be mistaken, and it was possible, that their opinions might not be much valued, because they had not had practical experience in the superintendence, or the construction of railways. He would, however, express his opinions on that point, and ask the meeting to take them for what they were worth. The most important question was, in what manner, or to what causes the 28·9 per cent. of the accidents to trains from running off the line, was made up. He believed, that fractured tyres produced 6·3 per cent., and, unfortunately, this class of accidents figured as largely in the year 1861 as they did in the year 1854, so that but little improvement seemed to have been made; but fortunately for the safety of the public, a different kind of inspector was called into play. In the winter of 1860-61 a severe frost occurred, and its representations to Railway Companies had been listened to. He had been told that there were hundreds of broken wheels in different yards belonging to various Railway Companies; he would not particularise those who had, year after year, and in the face of similar accidents occurring, persisted in a bad and unsafe mode of fastening the tyres upon the wheels. Some of the railways had taken time by the fore-lock, and were free from those mishaps; but still, in 1861, fractured tyres were, according to the reports of the inspecting officers, the cause of 6·3 per cent. of the trains running off the line. He believed he was fully justified in saying that this class of accident could be entirely avoided.

Fractured couplings, axles, wheels, springs, &c., produced 6·1 per cent.; but he was not so sanguine as to the future avoidance of this class of accidents, as with reference to those arising from the fracturing of tyres.

Passing through facing points, and over crossings, had occasioned 4 per cent. of the accidents due to trains leaving the line. He was afraid that per-centage would not decrease. The permanent way, including the defective state of the sleepers, treenails, rails, and keys, produced 8·6 per cent. Obstructions on the line—such as cattle, bales of cotton, which had fallen from trucks, and rails placed across the line, had only produced 1·7 per cent. The peculiar construction of the engines, used for drawing the trains had only been the cause of accidents to the extent of 0·7 per cent. To excessive speed 1·9 per cent. was attributable. It was an important fact, that 8·6 per cent. of the accidents to trains from running off the line, amounting altogether to 46 in number, had reference to the nature of the permanent way. It was remarkable that none of those accidents occurred on the broad gauge system. He had been for nearly eight years connected with the railway department, and he could not find a single instance of the road having been burst on the broad gauge system.

He was then referring to the 8·6 per centage of accidents, due to trains leaving the line from a defective state of the permanent way: that was a deduction founded on the opinions of the inspecting officers, and the question for the practical consideration of Civil Engineers engaged in the construction, or maintenance of railways, was, whether some improvement in the narrow gauge system of construction could not be effected. Rightly, or wrongly, a large proportion of that per-centage was attributed, by the inspecting officers, to the mode of fastening the chairs to the sleepers, by means of wooden treenails, and, even if the inspecting officers were wrong in their opinions, the fact of the trains getting off the line could not be disputed. Another element of danger had reference to the mode of securing the joints of the rails together; a third element consisted in the chairs, and their liability to break; and a fourth was in the keys, for securing the rails in the chairs, and their liability to become loose. In the permanent way of the narrow gauge there were too many parts. It should be considered whether their number could not be diminished, and whether the rails could not be attached more securely to the transverse sleepers. The experiment should be tried of laying down an increased number of transverse sleepers. Engineers in charge of narrow gauge lines might thus secure as good a permanent way as that of the broad gauge; and so prevent it from being so frequently burst asunder by the passage of trains.

Allusion had been made to crotchets of individuals: one of them related to the desirability of having two railway whistles of different tones. He did not think there was any use in concealing an opinion, especially if it happened to be a strong and a decided opinion. The broad gauge system of having two whistles on the engine,—one a signal whistle to call to a level crossing, or for a signal to be taken off; and the other, for conveying an instantaneous intimation to the guards, to apply the breaks,—was greatly to be preferred to the system on the narrow gauge, where one whistle was sounded for many different purposes. He held, that the correct principle to work upon, for the prevention of railway accidents was, that every one connected with the working of the train should know, at once, what he had to do when a signal was given. The signals should be so clear, that there should never be any mistake upon the subject; and if he added, that during the years he had mentioned, there had not been a single fatal accident to a passenger on the broad gauge system from a collision, or from a train getting off the line, he stated a very strong fact in support of the opinions he had advanced with respect to the permanent way, and safety of working, and it was also one, which would contrast very favourably with the number of persons killed upon the narrow gauge lines of the kingdom.

Another subject which had been taken exception to was, that he had not hesitated to condemn the practice, or rather the omission of the practice, of the Great Western Railway Company to place a break at the tail of their trains. He held it to be wrong to omit the break van at the tail of the train; for if anything was clearly made out by the accidents which had taken place in this country, long before he had anything to do with the Railway Department of the Board of Trade, it was, that there should be one break next the tender, and another at the tail of the train,—the one to receive the shock of running into an obstruction ahead, the other to receive the shock of anything running into the rear of the train. Another strong reason why he had urged that a break should always be placed at the tail of a train, had reference to travelling up inclines. Under such circumstances, there had been very serious accidents, caused by the absence of breaks at the tails of trains, or by the non-application of those breaks at the proper moment. It was quite true, that the Great Western Railway Company, after having had one or two narrow escapes, had taken what they thought, and what had indeed hitherto proved, to be an apparently secure mode of avoiding that class of accidents on that railway,—he meant, by strengthening the couplings. He should, however, be sorry indeed to see such a process carried out, with reference to the couplings on the narrow gauge railways, till they had greatly improved their narrow gauge permanent way, and had made it equal in point of safety to the permanent way of the broad gauge, and thus prevented the great liability, that prevailed at present, of trains getting off the line. Still he had never hesitated to condemn the practice of the Great Western, although he admitted that their system, as it had been recently worked, had been eminently successful.

The gradual introduction of distant signals was another great improvement which had been introduced both on the broad and the narrow gauge systems. He believed, that some of the officers of the Great Western Railway were, in the first instance, decidedly opposed to their introduction. No doubt many gentlemen now present, knew the strong objections that were at one time entertained to their use. He felt perfectly satisfied that railway managers would concur with him in saying, that the introduction of distant signals had been a very great improvement, and had considerably increased the safety of the public, and that it was not the introduction of too many signals, but the failure to use, or to observe the indications of signals, that caused so many accidents. He entirely agreed in the advantage of recording the speed of trains in travelling, and he had been told, that Mr. Ramsbottom, of the London and North-Western Railway, had invented an instrument which enabled an engine-driver, at any moment, to ascertain the speed at which his train was travelling. Judging from the evidence they gave, when any inquiry was made into an accident, there were no persons who were so little acquainted with the actual speed at which they were travelling as the engine-drivers themselves. Another alleged crotchet, had reference to the use of continuous breaks. He entertained a very decided opinion, that if a train could, by some such arrangement, be stopped in the same space that a single vehicle fitted with a break could be stopped, there would be a much greater chance of avoiding collisions. If railway managers, either from disinclination to incur the cost, or from any other cause, could not prevent two trains being on the same space between two stations at the same time, so as to keep a proper interval of space between two succeeding trains, then that was an additional reason why the proportion of break power ought to be largely increased. A congress of German railway Engineers, held in 1857-8, and which subsequently met in 1858, laid down a regulation, that the number of breaks which should be supplied to passenger and goods trains, should be entirely dependent upon the gradients. He differed partly from the German railway Engineers, as he thought that the proportion depended mainly upon the speed at which the trains were intended to travel. If the railway managers in England were content to let their trains travel at the rate of 20 miles per hour, the ordinary practice adopted in this country was good and sufficient: but when trains were forced along at three times that speed, and at times, even at a greater speed, the break power at hand ought to be very largely increased. It had been asserted that the inspecting officers had no practical experience. He confessed that he had none in the working of railways, but he went about a good deal on railways, and had made inquiries, in the course of which he had been informed by the officers of the Lancashire and Yorkshire Railway, which carried the largest number of passengers but one in the kingdom, that a much larger proportion of break power could be supplied by means of continuous breaks; and that after an experience of years, they had been found to be both effective and economical. He was sometimes told that this information was supplied from an inventor's line; but the same remark might be made with respect to nearly all the improvements that had been carried out on railways.

According to the German railway Engineers, the break power employed should be in the following ratio:—

For a gradient not exceeding	1 in 300	.	one break per six carriages.
„ „	1 in 200	.	„ per five „
„ „	1 in 100	.	„ per four „
„ „	1 in 60	.	„ per three „
„ „	1 in 40	.	„ per two „

The latter gradient was a close approximation to that of the Lickey incline, which had been worked with perfect safety for a number of years, by attaching breaks when the rails were slippery, but the total break power employed had been equal to that of a break to every carriage in the train. In France, the practice in attaching breaks ranged from the attachment of 1 break to 9 carriages, to 1 break to 1 carriage. Therefore, when he found in this country only 1 break attached to 13 vehicles, or 11 vehicles, he held that it was insufficient, and he only did his duty as a public servant in saying so on all occasions. Continuous breaks were used on one Metropolitan line, of a different construction to those on the Lancashire and Yorkshire Railway, and they were worked with perfect success. They were employed also on the Greenwich line: in fact, he believed they were gradually growing into favour. He did not insist on their employment, but he considered that there should be a greater proportion of break power put on in the manner which was most economical and most efficient.

With reference to the inspecting officers of the Board of Trade, he, in one respect, entirely agreed with Mr. Bidder. The inspecting officers, in the performance of the duties required from them, were placed in a very invidious position. They were sent to inquire into the circumstances relating to each serious railway accident that occurred, and at the same time there was no authority under the law for their doing so. It was a question entirely of sufferance; and he did not hesitate to say, that individually he should have felt that duty irksome and disagreeable in the extreme, if it had not been for the kind and open manner, in which he was invariably met by the officers of the Companies with whom he was brought in contact. On all occasions they had given him any information he chose to ask for, and called before him any person whom he wished to see; and if it were not for that fact, he should have felt the duty to have been one that he could not have performed. But at the same time he did not think, that any of the gentlemen whom he had so much pleasure in meeting on those occasions would have made the statement to the meeting which had been made by Mr. Bidder. He did not think so. It was the best satisfaction he had, to feel that the remarks which had been made as to his conduct by that gentleman were uncalled for, and, he believed, entirely undeserved.

Three particular accidents had been mentioned by Mr. Bidder. He referred first to the Tuxford accident on the Great Northern Railway; and he stated, that there were conflicting decisions of juries on that occasion. Colonel Yolland was not the inspecting officer who made the official inquiry into that accident. The gentleman who did so was no longer employed at the Board of Trade; but he believed—although he was not quite certain of the fact—that that Inspecting Officer was called by the Company as their witness: but what he was perfectly sure of was, that there was nothing in his report that any Railway Company could have taken exception to. The cases of the two other accidents referred to, were those at Hatfield, in which Mr. Pym lost his life, and that in which Dr. Baly was killed at the Epsom junction of the London and South-Western Railway. He believed, that the decision of the court of law with reference to the Hatfield accident had not yet been given; but as far as he recollected, there was nearly an equal balance of opinion on that occasion. Although he did not stay to hear the evidence given on the trial, he believed the effect of that evidence was such, that it left it open to impartial people to think, that the cause of accident arose from neglect on the part of the Company, in the use of a damaged rail. Colonel Yolland gave his opinion that it was caused by a turned rail which was damaged; and what was more, he knew the Engineer of the Company admitted as much.

He would now turn to that portion of Mr. Bidder's remarks which was even more personal to himself than either of the other cases. They had reference to the accident in which Dr. Baly unfortunately lost his life. Mr. Bidder drew their attention in the first place to Colonel Yolland having stated an opinion, that Dr. Baly's life might have been saved if there had been a larger proportion of break power at the tail of the train. He did not know that the Institution was exactly the proper place in which such a point should be discussed, but as it had been brought forward, he had not the slightest objection to state in detail his view of the case. The carriage in which Dr. Baly was killed ran, with five other carriages behind it, for a distance of 47 yards beyond the break, which lay on the bank on the left of the line, and it then turned over on to its side. There were four vehicles lying down the sides of the embankments between the two lines—the Epsom and Leatherhead Branch and the main line—besides the tender of the engine; and there was no evidence, or appearance whatever, that the carriage in which Dr. Baly was riding had been at all pushed forward after it had fallen on its side; and therefore it appeared to Colonel Yolland, that if that carriage could have been arrested 20 yards short of the spot, at which it fell over and killed Dr. Baly, it would have been quite possible, and even probable, that that gentleman might have been alive now. He did not ask the Members of the Institution to agree with that opinion; he was only giving them his reasons for thinking so. The accident was peculiar in another respect. They were correctly told by Mr. Bidder that the engine broke away; that the tender first went down the embankment, and was followed in succession by three carriages and the break van; and the strongest indication that he knew of, after the investigation of more than two hundred accidents, of the absence of a controlling, and retarding power, at the tail of the train, and that the speed of the train was great, was to be found in the reversed position of the carriages after the accident. Those carriages most distant from London, before the accident, were nearest to it after its close, with the exception of four vehicles, running freely upon the line, at the tail of the train, and two, immediately in front, one of them being the carriage which fell over with, and killed Dr. Baly. His argument was, that if there had been a break attached to the tail of the train, it would, if applied, have exerted a force to retard the impetus of the hinder part of the train, which was running freely on the rails without a break, whereas the reversed position of the carriages after the accident was evidence, both of the speed, and of the absence of a retarding force at the tail of the train.

As regarded the question of his having given an opinion, before the jury at Wimbledon, that the train would not have been so likely to get off the line, if it had been going at a greater speed:—The place where one of the carriages got off, was between an under bridge, a little more than 100 feet from the junction, and the junction itself. Within that space—probably at about 80 feet from the junction—and at about 120 feet from the junction, on the inside of the curve, there was a laminated rail, and there the cant of the outer rail was double the amount it ought to have been. Mr. Bidder had referred to Colonel Yolland's examination before the jury at Wimbledon. Now if a train was going slower, the cant of the rail did not require to be so great, as if the train was going fast; and inasmuch, as there was an excess of cant at the point where the laminated rail was situated, the wheels of the carriages would be more likely to come in contact with the laminated rail, on the inside of the curve, when the train was going slow than when it was going fast, because the cant must be increased, directly in proportion to the speed.

Another point to which Mr. Bidder had called attention, had reference to the middle wheel of the tender. He did not know whether any of the members were present at the inquest, but he did not think there was a doubt but that the officers of the Company had a strong opinion amongst themselves, at one time, that the middle wheel of the tender was the sole cause of the train going off. He did not know who pointed it out to Mr. Bovill, but that gentleman drew his attention to certain marks, which were found at a spot, about 3 feet before the train reached the facing points. Those marks were of such a character, as clearly proved to his mind, that they could not have been made by the middle wheel of the tender, but that they must have been made by some carriage wheel. He gave in his report, and he had since stated his opinion, that the cause of the accident was the tightness of the gauge on the curve, to the extent of three-quarters of an inch, when the gauge ought properly to have been wide. When he mentioned, that there were three vehicles, besides the tender, after the accident, of which some of the wheels were no longer true to gauge, and that some of those wheels might have run from London to Southampton, without risk, if there had been no tightness of the gauge, he had shown, that the state of circumstances after the accident clearly demonstrated, that there were causes which would have been sufficient to throw a carriage off the line, when it reached that part of the curve. In conclusion, he would remark, that Mr. Bidder had drawn attention to the state of the road—the goodness of the road after the accident. It would, perhaps, be sufficient to say, that the drivers of the Company had reported that piece of road before it was repaired on the Monday previous to the accident, and that they had again reported it after it was repaired.

Mr. HAWKSHAW, President, said, that whilst he was most anxious to give Colonel Yolland full opportunities of explanation in reply to Mr. Bidder, he must remark, that it was not desirable to reopen to its full extent, a question which had already occupied so much time before a court of law.

Mr. C. H. GREGORY said, that he had examined the permanent way after the accident took place, and before any alteration had been made in it, but he could not discover in it anything to account for the occurrence. He could not agree with those who considered, that a definite cause could be assigned to every railway accident, for, after many accidents, the derangement of the road and of the rolling stock was so great, that a practical man would be unable to say which was the cause, and which the effect. He believed that the authors of Papers, and of the official Reports on railway accidents, while themselves acting in perfect good faith, were too apt to lay down laws in reference to the causes of accidents, when, from the uncertainty of the causes, no laws could fairly be laid down. It had been urged, that by following certain rules collisions on railways would be absolutely impossible. With this view, it had been proposed, that trains should only follow one another at certain intervals of time, or that only one train at a time, should be allowed to run, on the lengths of railway between the stations; but he doubted whether either of these rules would be found in practice to insure absolute freedom from accident. Referring to the two axioms laid down for railway working, that there ought to be continuous breaks, and a break van at both ends of every train, Mr. Gregory submitted that those two laws, if followed absolutely, might be in themselves the causes of accident. There might be cases where a train had ample break power elsewhere, and where the requirement of a break van at each end might unnecessarily overload the engine; or where trains had to be made up, or separated at stations, the shifting of the break vans to the ends of the altered trains, might involve unnecessary shunting. The result, in either case, might be increased obstruction of the main line and unpunctuality. The assumed advantage of a continuous break, which would act on all the wheels of a train by one operation, was, that by its use, a train could be brought to rest in a minimum of time and distance; but, in fact, these continuous breaks depended upon the perfect action of so many parts, all more or less liable to derangement, that, in his opinion, a reliance upon them might produce the most fearful results. Colonel Yolland also appeared to assume, that it was of great advantage to multiply signals. Mr. Gregory advocated the use of as few signals, as were consistent with safety. The multiplication of signals, and especially of self-acting signals, introduced elements of danger, by complicating what should be as simple as possible, and diminishing in railway servants the feeling of individual responsibility. One of the most serious railway accidents on record had, he believed, been caused by trusting to a distance signal, which when too late, was found to be out of order. He therefore concluded, that it was unsafe to lay down any absolute law, with regard to the number, or position of break vans to be attached to a train, or the special class of break, or the multiplying of signals. He hoped that what he said would not be regarded as in any way reflecting upon Colonel Yolland. He differed from some of his opinions and official decisions, but cordially acknowledged the careful attention which he had shown in the discharge of his duties, and his invariable courtesy, even when Engineers had disputed decisions which Colonel Yolland had given as an inspecting officer.

Mr. G. B. **Bruce** would admit, that the permanent way of the narrow gauge lines, with cross sleepers, would be more readily knocked to pieces, by a train off the line, than the permanent way upon the broad gauge. Although the longitudinal sleepers of the broad gauge would keep their place better, under those circumstances, it did not follow that a narrower gauge would be a necessary cause of accident. The displacement of the permanent way might be effected after the train had got off the line, and might not be the consequence of imperfections in the permanent way itself. Therefore, although the permanent way of the narrow gauge, might be more displaced after an accident, it did not necessarily follow, that it was less safe for a train to travel along it. The objection, that the first Paper contained nothing, that was new within the last twenty years, was, he thought, unnecessarily severe. It was by no means an easy task to write a new Paper upon railway accidents. He did not very well see how the Author could have done otherwise than use the reports of the Board of Trade, or assume other results than those; and, having taken them, to offer suggestions, as to how some of the accidents might be remedied, leaving it for the Institution to discuss them in detail. Had the Author brought forward entirely new expedients for obviating accidents, he would perhaps only have brought upon himself worse censure for acts of commission, than he had received for acts of omission.

He gathered from the Paper that the Author objected to the suspended fish-joint, and that he preferred the bracketed chair with a cast-iron fish on one side, and a malleable fish on the other, resting on the chair. His own opinion was, that although the suspended fish-joint, as a mechanical contrivance, was by no means perfect, yet, at the same time, it was the best which had been obtained up to the present time. As regarded the weight of the engines, no doubt it was unwise to put upon a line an engine heavier than was absolutely necessary for the carrying of the traffic. There was danger in increasing the size of the engine without, at the same time, adding to the bearing surface, by increasing the number of wheels, and that was a subject fairly deserving of consideration.

With reference to those accidents which arose from engines and trains going off the line, if the locomotive engines on English railways were made with bogies like those on the American railways, they would be able to run upon rougher roads than they did now. It was a fact, that an ordinary English train would not be able to run a hundred miles, upon some of the American lines, without going off the rails. That was to a great extent owing to the principle which Mr. Bidder spoke of, as the principle of compromise, being more fully carried out in the American system. The American roads were constructed in a very rough manner; and what was necessary upon a rough road would be a safeguard upon a better road. He was therefore glad to see, that bogies were being introduced on some railways here. The old-fashioned notion, that bogies were only suited for sharp curves, and imperfect roads, was not a sound one. They could be put upon straight and level roads with advantage. Then as to the communication between the guards and the drivers.—The large American carriages, with a strap along the centre communicating with a bell, and free passage through them at any moment, afforded all the protection that could be desired. English Engineers and Railway Companies might with advantage borrow a hint or two in these matters from the other side of the Atlantic. With regard, however, to the bogies, it would not be borrowing from them; because they were originally made at Newcastle, by Mr. Robert Stephenson, and sent to America—where those connected with railways had had the good sense to adopt, what in England had failed to be appreciated.

Mr. Henry Shaw expressed his concurrence in the opinion, that the break-block at present in use was not applied with the greatest mechanical effect. He had invented a break-block, which caught the wheel in its front, and considerably below the centre, by which means the motion of the wheel, aided and secured, the action of the break.

Mr. Thomas Webster, did not know how the present system of inquiry into railway accidents could be amended: if the tribunal was established which had been proposed by Mr. Bidder, there would still be a conflict of opinions amongst the railway officials or managers, who would have to judge as to what ought to be the amount apportioned in a case of compensation. Each case must be decided upon its own merits; and though he had no preference as regarded the trial of such cases, either by a jury or by arbitration, yet whatever the tribunal, there would still be the same difficulties. As regarded scientific evidence, it had been overlooked in the discussions, that the witnesses were generally speaking to matters of opinion, and not to matters of fact. There might be every shade of opinion. There might be half-a-dozen witnesses on one side, and the same number on the other side; but he wanted to know how they would arrive at the truth, except by calling experts to express matters of opinion, the facts being, in the majority of cases, beyond dispute. But the question was, what was meant by scientific evidence? He considered the man who was skilled in judging of the different qualities of cotton was an expert: he was just as much a scientific man, in his way, as an engineer, or railway official was, when giving an opinion as to what might be the cause of a railway accident, or an opinion founded on facts about which there was no dispute; and therefore the question involved in this discussion, as to the nature of the tribunal, and how the facts in dispute were to be ascertained, were at the root of every inquiry to get at the truth: such an inquiry was one in which there must be experts to give an opinion, so that whatever tribunal might be substituted, it must not be forgotten, that they were dealing with questions of opinion, and not of fact; and that upon questions of opinion great diversity must be expected to exist.

Captain TYLER said, that the question of compensation to which the discussion had now turned was an important one. He agreed, that some better tribunal might be introduced, to decide what compensation should be afforded in cases of injury and death. There could hardly be a worse system, than that which existed at the present moment, and he felt that there was some force in what Mr. Bidder had said on the subject. When railway accidents occurred, his colleagues and himself were sent to inquire into them. They had every facility afforded to them by the Railway Companies; they were met in a kindly spirit; and he believed with Colonel Yolland, that the railway officials would not speak of the Inspectors of the Board of Trade as Mr. Bidder had done. The Government inspectors were sometimes, called either for, or against the Railway Companies, after the accident, to give evidence in courts of law, in cases in which compensation was demanded. They were served with a subpœna, and it was not their fault that they were obliged to give evidence. He thought there was a simple mode by which this alleged partizan evidence might be avoided. He would recommend that, instead of calling a number of Engineers on both sides, three Engineers, should be appointed to act in a judicial capacity, and to advise the judge. He did not see what possible objection there could be to such an arrangement; and he was convinced that, if it was adopted, it would prevent much unpleasantness, and what was now a stain upon the honourable, useful, and important profession of Civil Engineers.

It had been said, that the reports of the Board of Trade were, in all cases, partizan reports against the Railway Companies, and some cases were adduced, to which Colonel Yolland had already replied. With respect to one accident, on which it became Captain Tyler's duty to report, namely, that which occurred at Tottenham, on the Eastern Counties Railway, in February, 1860,—that case gave rise to a great deal of litigation, one jury having reversed the decision at which a previous jury had arrived. He would appeal to the Engineer of that Company, to say whether he was in any way a partizan in that case? It so happened, that when the decision was given against the Company he was not called, and that he was present in the second case, which went in favour of the Company. His evidence was even then of an unimportant character, and not upon the cause of the accident, and he had the pleasure of hearing his official report quoted equally in court by the counsel on both sides. In his selection of that case, therefore, Mr. Bidder had chosen an unfortunate instance in support of his statement.

After what had been said on the subject of accidents, there was little that he desired to add. There was no necessity for complicated contrivances such as those of which Mr. Babbage had spoken, for finding out the causes of accidents, though it was sometimes to the interest of those concerned to make them appear more mysterious than they really were. As far as his experience went, the causes of these accidents were not in a general way involved in any mystery; nor did they require complicated inventions for their prevention. Careful construction, careful maintenance, and careful management, were the principal remedies required. Defects of management were more frequent causes of accident than defects of maintenance; and defects of maintenance, again, than defects of construction. The figures which had been given, by Colonel Yolland and others, varied according to the periods over which they extended, and the mode in which the facts were stated. From an analysis of a longer period, he found that about 58 per cent. of the accidents reported on by the officers of the Board of Trade arose from collisions; 25 per cent. from trains going off the line; 6½ per cent. from facing points; 4 per cent. from the bursting of locomotive boilers; and 6½ per cent. from miscellaneous causes, such as the breaking of couplings, accidents at level crossings, or obstructions at the side of the line, and so forth. Of those which were caused by trains going off the line, one-third were due to defects in the permanent way, and two-thirds to defects in rolling stock. These last arose principally from the fracture of tyres, and this class of accident might now, by the adoption, as rapidly as circumstances would permit, of the new methods of fastening the tyres to the wheels, be almost entirely, if not altogether prevented.

Professor AIRY—through the Secretary—remarked that, although the impression was widely extended, that the greater weight of modern locomotives helped to keep them from running off the rails, the following considerations would show that such an opinion, if taken in the literal sense of the words, was without foundation; although, if greatly limited, it expressed an idea which ought always to be present to the mind of the Engineer. The practical occurrence, which gave rise to the necessity of any consideration of that kind, was the existence of accidental inequality upon the rails, or upon the tyres of the wheels; and the question to be examined was,—what would be the result of the shake which the inequality would produce, according as the engine was very light, or very heavy? If the engine was very light, and if the rails had that extreme firmness which was necessary for supporting very heavy weights, then the shake in question would toss the light engine high up; not because it was light, but because the rails did not yield. But if the rails had only that degree of firmness which was proper for light weights, and yielded to the heavy strain which was produced by the sudden interposition of a hard obstacle, then the effects of the shock would be divided; the rails would yield, and the engine would be raised, and probably neither movement would take place to a pernicious extent. Similarly if the engine was very heavy, and if the rails were correspondingly firm, the strain which was produced by a hard obstacle would partly raise the engine, and partly depress the rails, and probably little injury would be done. But if the rails were not firm, the strain would scarcely raise the engine, but would depress the rails; the engine would plunge, as on a yielding road, and, if not immediately thrown off, would so much injure the road, as to endanger the next train. It would, therefore, appear that, to adopt an expression previously used, the whole economy of a railway was a system of compromise, and the success of the arrangements would depend upon its terms. It appeared to be as dangerous to put a light engine upon very firm rails, as to put a heavy engine upon yielding rails. The sagacity of the Engineer alone, could practically effect the solution of the question, as it appeared to be beyond the powers of mathematics.

The Earl of SHELBURNE,—Chairman of the Great Western Railway Company,—wished to ask Colonel Yolland two questions, with reference to what had fallen from him, on the subject of train arrangement, and particularly with regard to break power.

He had understood Colonel Yolland to state, that the number of accidents, resulting from fractures of tyres, was the same in 1861 as in 1854. He would ask whether, that was in proportion to the amount of rolling stock employed, or whether it was an absolute comparison. The second question was with reference to break power—especially continuous break power. When the Earl of Shelburne was first connected with railways, this was a matter which was much discussed, and he had never heard the objections then made to the employment of continuous break power, and which had been repeated this evening, completely answered. Having heard that the Board of Trade advocated that system of breaks very strongly, one of the first questions he asked, after being appointed chairman of the Great Western Railway Company, was, how it was considered that Company stood in the matter? Was there any prejudice among the officers against the system of continuous breaks? or had it been tried in a way, to test fairly its value as an improvement? For if any real improvement could be devised, nobody was so interested in adopting it as Railway Companies. To the best of his ability, he had examined into the question, and endeavoured to obtain the best opinions upon it. One objection he heard was the same which had been urged by Mr. Gregory, and still stronger objections were made, in the case of trains requiring to be subdivided, owing to the additional difficulties in the way of disconnection, and other circumstances. He should be glad to hear some explanation upon those two particular and most important points; for whichever might be the right system, without question, a right distribution of the necessary amount of break power was among the most important matters a Railway Company had to consider. He concurred in the opinion, that there was no class of persons, from whom suggestions for improvement were more likely to proceed, than from the executive officers of railways. It must be remembered that they were daily witnesses of the experiments actually going on, and had all the advantages of great practical knowledge. With reference to this point, however, one of the great misfortunes which all Railway Companies had to encounter, was owing to the present system of parliamentary legislation. The system was such, that half the officers of the Companies were engaged, not only during the session of parliament, but for a long time previously, in preparing to fight their parliamentary battles, and at the close of the session, it was some time before they settled down to their regular duties. Although the Company with which he was connected might be as guilty in this respect as others, he must say that the system of legislation was one, which encouraged litigation between Companies, and in addition, practically interfered with the progress which Railway Companies might make, in the details of working their lines.

Colonel **Yolland** said, that the question with reference to tyres stood thus. In 1854, five trains were reported upon by the inspecting officer of the Board of Trade as having been thrown off the line in consequence of fractured tyres; and in 1861, seven similar cases were reported upon. But it was to be borne in mind, that in the early months of the latter year the frost was more intense, than it had been for a great number of years. That probably increased the number of casualties beyond what might otherwise have been expected. It should, however, be understood that the number stated—seven—did not at all represent the actual fractures of tyres which took place. He was told that they occurred by hundreds.

With reference to the question of continuous breaks, and especially as regarded the subdivision of trains, his argument was, that a large proportion of the main line trains ran at excessive speeds throughout the country, and required a much larger proportion of break power than was usually provided. When a train running on the Great Western Railway arrived at such a station as Swindon, it was sub-divided, and a part of it went off to Cheltenham and Gloucester. Such a portion, according to his view, might be connected continuously together by breaks; but it must not be understood, that he advocated a continuous connection throughout the whole of a long train. Supposing a train to start from London with—as was the custom of the London and North-Western Railway—two guards and a conductor; his argument was, that each guard might have the control of three carriages furnished with breaks. One set of carriages would drop off at Rugby, and go on to the Midland; another portion of the train would go to Stafford and Crewe, and on to Chester and Holyhead; another portion would go to Manchester, and the main-line train would go on to Scotland. He was not aware of any difficulty in disconnecting the apparatus which secured the continuous breaks together. At the same time, he did not specially advocate continuous breaks. It was immaterial to him how additional break power was provided; but he was told that continuous breaks were economical in their application and management, and that they afforded a much larger proportion of break power for trains than the ordinary system, without any necessity for sending additional guards; and he did not believe that there was any mechanical difficulty involved in their use.

Mr. J. **Allen Ransome** said, that considering the large extent to which, whether rightly or wrongly, the system of treenails had during the last eighteen years been adopted, upwards of 3,000 miles of railway having been constructed on that plan in this country, and as many more on foreign railways, and considering how much they had been both used and abused, he thought the question of treenails had scarcely had the full measure of consideration which it deserved. The invention of the compressed oak treenail was due to his late partner, Mr. Charles May, but Mr. Ransome had been personally interested, in diffusing the knowledge, and the advantages, of the treenail system, as widely as possible, firmly believing them to form the best fastening of the chair to the sleeper which had ever been in use. Col. Yolland had given an analysis, in which he stated that 8·6 per cent. of the accidents was attributable to the bad state of the permanent way, arising from the displacement of the lines of rail. Now this might have been due to several causes. A broken chair, a drawn spike, a bad rail, a rotten sleeper, or imperfect ballast, would cause disruption of the road, as well as a defective treenail. So that taking the probable proportion of these six sources of accident, to be equal, it would reduce the average of the accidents due to treenails to a very small per centage. But in order to arrive at sound conclusions, there was a still further analysis needed, for which he had no means of obtaining the data. This was the number of accidents that had occurred where perfectly compressed oak treenails had been used, in comparison with simply turned uncompressed wooden pegs. Whenever an accident had occurred which was attributed to the use of treenails, he had instituted a careful inquiry; and in almost every case he had found that a spurious imitation of the compressed treenails had been used. Many and careful experiments had been made to test the holding power and strength of the compressed treenails. Heavy blows had been given them with a pile-driver, in a direction similar to that which the concussion of the wheels of a locomotive would affect them, and their holding powers had been found amply sufficient to retain the chair in its place. There was no plan, he believed, by which the perfect securing the iron chair to the wooden sleeper had been so well attained, as by the use of a properly compressed oak treenail. He would not assert, that if the best treenails were used accidents would never occur. But it was certain, that in some of the cases, in which treenails had recently been pointedly alluded to, as the cause of accident, the Companies had not been supplied with any compressed treenails from his firm for the last twelve or fourteen years, but had been using uncompressed pegs. The inference therefore was, that either the treenails must have lasted for a longer period, than fourteen years without renewal, or that the chairs had been attempted to be secured by inferior treenails.

Mr. C. B. Lane said, that the best permanent way, for any given place and set of conditions, was that which produced the most complete simultaneous adjustment of a number of considerations. Some were mechanical, and others, although they frequently demanded the greatest attention of the Engineer, were purely economical. The general question, however, involved too many independent variables to be embraced by any single formula. A good permanent way could be made by a variety of methods. It was generally admitted that the double-headed reversible rail, notwithstanding the disadvantages arising from the number and complexity of its fastenings, was the most economical on account of its greater duration. That fact had been impugned; and it was possible—looking at the state of railway traffic in this country, the great weights carried, and the very high velocities at which the trains travelled—that that form of road might no longer be the most economical in England; and indeed some remarks made by Colonel Yolland at the last meeting on the permanent way of the Great Western Railway seemed to point to that conclusion: but in a new country like Brazil, his experience there led him to maintain that it was the most economical form of road.

There was one arrangement in Mr. Brunlees' permanent way, which Mr. Lane considered conducive to safety, and worthy of more general adoption. He alluded to the wooden keys being placed inside, instead of outside the road. In a tropical climate, that was a very important point; for from the wide range of temperatures to which the wooden keys were exposed in contact with the iron, if some preventive means were not adopted they would shake out, and thus produce a tendency to railway accidents. This tendency was obviated by the form of road adopted by Mr. Brunlees. On the general question of railway accidents, he would remark, that the statistics which had been brought before the Institution showed, that in this country, travellers paid a very heavy discount for the comparative advantages, which they enjoyed over some of their continental neighbours. It had been asserted, that if the sources of railway accidents were decreased in one direction, they would only be increased in another, which amounted to saying that railways and railway management were now perfect. To say that the absence of precaution was a good safeguard against accidents, was to express an opinion not likely to be consolatory to the general public, and one which ought not to go forth from the Institution without contradiction. An opinion had also been given that the adoption of two whistles upon an engine was likely to be followed by fatal and disastrous results. As most gentlemen present were aware that such a mode of signaling had been in use, on the Great Western Railway, for the last quarter of a century, and that no danger or inconvenience had resulted from its employment, it was obvious that such apprehensions were entirely unfounded. In the course of this discussion trial by jury in cases of railway accidents had been impugned. It could not be denied that juries sometimes arrived at very clumsy conclusions; but unless some better mode of obviating that difficulty could be brought forward than that which had been suggested in the course of the discussion, he thought it would be better that no alteration should be made.

Captain GALTON, in reply, said that the general facts which he had adduced had he thought been admitted. It had been stated that the occurrence of railway accidents was valuable as inducing vigilance. He could not admit that accidents were desirable if they could be prevented, and his whole argument was, that so long as the causes of railway accidents were shown to have been such, that they could have been avoided, it might be hoped, that the recurrence of similar accidents would in future be prevented. It had been stated, that the Midland Railway had been worked for several years without any serious accidents. That railway was a fair example of railway communication in this country. It combined on its lines almost every variety of traffic: if, therefore, that railway could be worked without accident for a series of years, why should not other railways be worked with equal safety, provided proper care were taken?

He would say a few words upon a point in his Paper which appeared to have been misunderstood. He had endeavoured to convey as his opinion, that there should be an executive head to every railway, not that it was desirable that the whole of the directors of a railway should be limited to being upon that direction only. He thought, much good resulted from the wider experience which directors obtained, from having under their observation several railways, and several varieties of commercial enterprises. For the general purposes of railway direction, such wider experience was of great benefit; but he thought it was essential to the efficient conduct of any large undertaking, that there should be a responsible head; not that he should interfere with the details of management in the several branches; but that he should exercise a continuous supervision over its working, and act as a check, perpetually present, upon the different officers, and upon the manner in which they were conducting their business. He considered, that the several officers of a Company, should be responsible for their several departments, and that the head of each department, should have full control of all persons employed in that department.

The next point to which he would direct attention, would be the question of compensation. Exception had been taken to the introduction of that subject. But notwithstanding that, the question was so mixed up with railway management, that he considered it a matter to be brought before the Institution. The argument he had attempted to bring forward was, that the present law was objectionable. It was injurious to the community at large, inasmuch as it encouraged litigation; it was unjust to the Railway Companies, because it frequently gave heavy compensation in cases, where the accident which had occurred had been due to causes, which were very remotely traceable to the Company, and gave, sometimes, very small compensation in cases of gross negligence, because the payment was dependent upon the social position of the traveller. It was injurious to the sufferers, because they were liable to be put to great expense in suing for compensation, and when they failed in establishing the liability of the Company, they were obliged to bear the whole cost of the legal expenses.

He did not at all imagine, that litigation could be entirely prevented; but he believed, that the course he had suggested would so far diminish it, as to render it of very rare occurrence. In the first place, what he had proposed was, that the Companies should be liable for the occurrence of every accident. By that means, the inducement to litigation would be reduced to the smallest possible point. He did not think that there was any reasonable objection to such a proposition; because in some way, or other, every accident could be remotely traceable to the Company's acts or omissions. If, for instance, a portion of a railway was washed away by a flood, it might be argued in a court of law that the reason of the flood being injurious was, either that the line was not raised sufciently above the flood level of the district, or that sufficient waterway was not originally provided. Similarly, if a tyre broke, the injury from the tyre would be due to the fact that the tyre had become detached from the wheel; and if it could be shown, that there was some method in existence, by which tyres when broken could be prevented from becoming detached from the wheel, it might be argued, that the Company was liable for the accident from not having adopted that method of attaching the tyres. Juries had found verdicts for persons injured in cases of fractures of tyres, when no direct negligence could be shown; so that practically, every accident to a train depended in a more, or less remote degree, upon the management of the Company; that is to say, it might be proved that the Company, or their servants were blameable, in a more, or less remote degree, for every accident. But if the present law were altered, so as to make a Railway Company liable, for every accident to trains that occurred beyond the control of the passenger, it would clearly be reasonable, that Railway Companies should receive some compensation for what they gave up; and he proposed, that that should be arranged by limiting the amount of compensation to be paid to passengers according to the class of the passenger; but that the passengers should be allowed to pay a small sum, if they desired to insure to themselves a larger amount of compensation in case of accident. But independently of this reason for limiting the compensation, the Companies were entitled to have the compensation limited upon other grounds. Railway Companies were bound to convey passengers at rates which were fixed by Parliament, and which were required by law to be equal under similar circumstances. Any man might take a ticket—a third-class ticket—whatever might be his station in life, and the Railway Company could not refuse to convey him, upon the ground, that if an accident occurred, he would be entitled to very heavy compensation; whereas, a man of low rank of life, who might take a similar ticket, would be entitled to scarcely any compensation. Upon that ground, he thought justice to Railway Companies demanded that some alteration in the law should take place; and he therefore proposed, that compensation should be limited in amount, and be made proportionate to the class of carriage in which the passenger was conveyed. There seemed to be some question as to how such a plan would work. His proposal was, that a sum should be fixed in case of death, and that up to that amount, passengers should recover, in proportion to the extent to which they were injured. Of course, if the passenger thought the sum which the Company offered was insufficient for the injury the passenger had sustained, he would be able, as now, to bring the case before a jury, who could award up to the maximum fixed for death, in the class in which the passenger was travelling. He did not suggest that such cases should be brought before any other tribunal than a jury. But he thought that such an arrangement, by abolishing the question, as to whether the Company were liable for the accident, and by placing a limit upon the compensation they should pay, would reduce the great evil of litigation, to the smallest possible degree.

Mr. BRUNLEES, in reply, said, that it was gratifying to him, that notwithstanding the length of the discussion, none of the facts put forward in his Paper had been controverted. It was true, that an attempt had been made to question the accuracy of the table which exhibited the classification of the different kinds of accidents, because the results, so shown, did not agree with the special proportions which obtained in the case of the Midland Railway; but it was scarcely necessary for him to repeat, that the table in question did not apply to the case of any single railway, but was an average of the whole of the accidents which had occurred on all the railways of this country. In compiling it he had taken the only reliable and, indeed, the only available data, —the returns of the officers of the Board of Trade. Considering that those returns showed that 76 per cent. of the accidents were attributable to inefficient management, it might have been reasonably expected, that the views of some of the railway managers on that point would have been put before the Institution. Only one had however spoken on the subject, and his remarks were limited to the anachronism, that a Paper upon events which had occurred during the last seven, or eight years might have been brought forward twenty years ago.

The Institution was greatly indebted to Professor Airy, Mr. Siemens, and Mr. Bruce, for the practical spirit in which their several suggestions had been brought forward. It was to elicit such contributions that he had written the Paper. Although a perfect means of preventing accidents might not suddenly be presented, yet the ideas which had been put forward might occupy the attention of those, who had the necessary knowledge and opportunity, and would ripen into practical effect hereafter. It had been erroneously supposed, that he had contended for a high standard of education, as a qualification for engine drivers, and pointsmen; but, on the other hand, he certainly considered, that if railway servants could read the rules and the time-tables, they would be more responsible for their actions. Another point on which he had been misunderstood was, as to the proper weight of locomotives: he did not advocate the employment of light engines, he had simply drawn attention to the fact that, all things considered, they were heavy enough for the bridges which had been constructed at an early period, and that moderate-sized engines were handier, and safer to work. Objection had been taken to the employment of a danger-whistle in addition to the ordinary one. Such an arrangement was in general use on the Great Western Railway. In addition to the utility of a danger-whistle as a signal to the guard to employ the breaks, he believed that nothing could be of more service to a passenger than a notification of a coming collision; as he would thereby have time to place himself in the best position to meet the coming shock, and so might save both life and limb. Under such circumstances, Mr. Brunlees considered that "to be forewarned was to be forearmed."

It had been stated that a railway was in effect the result of a system of compromises. In many cases such an assertion was but too true. But at the same time such a state of affairs proved that there must be something radically wrong. The only real compromise required on a railway was, that there should be an amount of elasticity in the road, sufficient to meet the rigidity of the framings of the rolling stock; but the more truly the road was kept in gauge, and the smoother its surface, the less chance there would be of accidents. It had further been argued, that if for a time there was a cessation of accidents, carelessness would ensue, and that thus, the average number of accidents would be maintained. Such an argument might be logical, but its applicability was very questionable. The discipline on English railways might at least, be so improved as to put them on a par with those on the Continent. It would be well if those intrusted with the management of railways devoted themselves, in an earnest spirit to ascertaining, and diminishing, the cause of accidents. If any new incentive was needed to such a course of action, it might be found in the return of railway accidents during 1861, which had been published during the last week. An abstract of that return was contained in the following extract from one of the daily papers:—

> "RAILWAY ACCIDENTS.—A small but most remarkable blue-book, of eighteen pages, has just been issued, enumerating the number and nature of railway accidents on all the lines of the United Kingdom, in the year 1861. The statement, tabulated throughout, is very dry and formal, yet terribly instructive notwithstanding. The summing-up shows, that in England and Wales, 44 passengers and 22 railway servants were killed from causes beyond their own control; and 24 more passengers and 66 railway servants lost their life, from what is stated to be 'their own misconduct.' The number of injured passengers amounted to no less than 769, of which only 7 were entered for 'misconduct;' while of railway servants 56 were injured, 13 of them through 'want of caution.' Besides some 60 trespassers and so-called 'miscellaneous' individuals—whatever that may mean—had their heads cut off by passing trains. In North Britain railway accidents were comparatively scarce, the well-known Scotch caution evidently prevailing throughout. Ireland was still more fortunate in the year 1861, having only to boast of 4 killed passengers, and 16 'misconducted' railway servants, besides 7 fatal trespassers. The grand total for the United Kingdom is, nevertheless, formidable enough, representing no less than 284 persons killed, and 883 wounded by railway accidents. In this awful list of sacrifices, paid for the benefit of cheap travel, the London, Brighton, and South Coast Railway leads the way, by 23 killed, and 209 wounded; closely followed by the little Hampstead Junction line, with 15 killed and 317 wounded. Very few lines in England show an entire absence of casualties; and, in fact, the only railway of note, on which not a single passenger or servant received injuries, was the Eastern Counties."

To say that such a catalogue of accidents, terribly disastrous in themselves, and scarcely less disheartening in their pecuniary consequences, was a necessary evil connected with the English railway system, detracted greatly from the reputation of the engineering profession. Unfortunately the penalties devolving upon Railway Companies as carriers were so heavy, that they were obliged, in self-defence, to endeavour to trace every casualty, to other causes than remissness or neglect upon their parts; and the careful scientific investigation necessary for future improvement gave way to this necessity. He would recommend to the attention of those connected with railways the trite English saying, "Prevention is better than cure." He hoped that all, according to their several positions, and especially Engineers, would devote themselves to endeavouring to lessen this peculiar phase of human suffering, rather by trying to lessen the number of railway accidents, than by providing the means for obtaining compensation for them after they had occurred.

Mr. HAWKSHAW—President—thought it was not desirable that the Members of the Institution should trespass further than was possible upon the province of the legal profession. He quite admitted that they were brought so much in contact with legal proceedings, that they could not do otherwise than form opinions on such subjects; but, at the same time, he submitted that the Institution was not the place in which such opinions should be expressed. When in courts of law, or before parliamentary committees, each gentleman could take his own course; but he thought it better that Mechanicians and Engineers should, as much as possible, confine their suggestions to physical means of preventing railway accidents. These observations were not meant to apply to Captain Galton's Paper, but to some of the remarks which had arisen in the course of its discussion. From the post which that officer for many years held in connection with railways, he had become as it were an adjudicator, not only upon mechanical points, but upon other important matters and regulations for the prevention of railway accidents; and his views on those subjects were at all times worthy of the most careful consideration. The Institution was greatly indebted to him for his valuable Paper. With many observations in that Paper Mr. Hawkshaw quite agreed, but from one or two he differed, more perhaps with respect to the terms used, than in any other point of view. For instance, Captain Galton thought one of the directors of every railway should be made an executive officer. On a little consideration, it would be seen that such an arrangement would be impossible. An executive officer should be a person who could be discharged if he neglected his duty. A director could not be discharged. He was elected by the shareholders for a period of years, and he might remain in that position, whether he discharged his duties efficiently, or otherwise, until his term of office expired. He thought it quite right, that there should be upon every railway some person who would have the responsibility, under the Board, of its general arrangements, and that responsibility should be carried to such an extent as to make him careful not to neglect his duties; but he did not think that it would be advisable to elect a director to fill such an office.

With regard to the question of compensation, it had been suggested that, instead of leaving it to be ascertained whether a large amount should be given, or nothing, some fixed sum should be levied for accidents to first, second, and third class passengers, and that a definite sum should be paid, whether the Company was to blame, or not. Such a scheme would not be good, even if it was practicable; but he believed that it was not so. No Company would pay a sum of money where it was not to blame. Thus if a man was to throw himself out of a carriage window, he understood Captain Galton to say that a fixed sum was to be paid, without raising the question of whether the Company was to blame.

Captain **Galton**, in correction, said: that would be an accident within the control of the passenger, and therefore no compensation would be awarded.

Mr. **Hawkshaw** had understood Captain Galton so to put the case that the compensation was to be fixed, whether the Company was to blame or not. Again, Captain Galton had alluded to the case of Companies having wheel tyres, which when broken would leave the wheel, and had assumed, that that should be taken as a ground of liability. Mr. Hawkshaw was perfectly aware, that modes of attaching tyres to the wheels had been devised which would prevent the broken portions from leaving the wheels. But what was to be done with the rolling stock of the railways, made previously to the discovery of that plan? The Companies could not be called upon to discard all that stock from use; and if not, were they to be liable to penalties, if a tyre broke, and left the wheel, and caused an accident? He mentioned this to show that these matters required judicial consideration, and that it would not be just to arrive hastily at the conclusion, that in every case, because a tyre broke the Company should be liable, though the stock was made years before the new plan of fastening tyres was introduced.

Mr. Hawkshaw agreed to a great extent with the points brought forward by Mr. Brunlees. It was quite true, as one of the Members had remarked, that matters were repeated in the Paper, with which he believed all present were supposed to be well acquainted, and some gentlemen seemed to take objection to the reiteration of matters so well known; but, from his own experience of railways, he could say that many of those things, though known, were not always attended to. Thus it was of the greatest importance to have good ballast, and a good permanent way. But it must be admitted that, if one thing more than another required to be reiterated, it was the necessity and desirability of attention to that point. In some cases it was with difficulty, that Engineers could secure it, in consequence of false notions of economy, that were pressed upon them by persons who wished to maintain the permanent way at the smallest cost, without reference to the goodness, or badness, of the road: nothing could be more important, as respected the safety of the public in travelling upon railways, than the uniform goodness of the road. On one or two points he did not agree with Mr. Brunlees. He argued against the employment of heavy engines. Mr. Hawkshaw recollected the time when he held similar views; but, as the traffic increased, Railway Companies were compelled to have recourse to heavy engines: they could not help it; nor did he yet see any limit to the weight of engines. They would probably require to be heavier than they were at present, unless a facility was acquired of multiplying trains, by making separate railways for passengers, and for goods. Those heavy weights could only be carried by using better materials for the permanent way, and by having rails of superior metal. The probable solution of the problem would be that, eventually railways would be made to carry passengers only, and other railways to carry goods only. At all events, so long as the traffic went on increasing, the weight of the engines could not be diminished.

It had been observed by Mr. Brunlees, on the question of rolling stock, that a fixed rule ought to be adopted, with regard to the height and width of the buffers. In India, rules of that sort had been agreed upon, by fixing a standard not only for the width and height of the buffers, but also for the carriages. Those rules were very important, and secured something like precision and uniformity of dimensions in the rolling stock. In this country there had been no meeting of Engineers, that he was aware of, to determine fixed rules, as to the width and height of the buffers, or as to the width and height of the carriages, and the existing want of uniformity was the result.

Upon the question of fish-joints, Mr. Brunlees was in favour of those supported by sleepers. Sir Joseph Paxton, on the other hand, expressed himself in favour of the suspended fish-joints, and stated that the former plan had been generally abandoned. So far as Mr. Hawkshaw was concerned, that was not the case, as in the last line he had constructed the fish-joint was supported by the sleeper. On the Great Western Railway, it was obvious that the fish-joint must of necessity be supported, on account of its being laid on longitudinal timbers. The fact was, it was not very material whether the fish-joint was supported or not. In constructing railways, the object should be to render the deflection of every part over which the weight passed as uniform as possible. When that was done, all was effected that was necessary or possible. He had lately passed over a railway where the fish-joints were suspended, and he noticed that in many cases the sleepers were brought up to one end of the fish, while the next sleeper was 2 feet, or more away from it; so that on one side the sleepers were sometimes 2 feet 6 inches away from the fish, and on the other side only 7 inches or 8 inches away. Nothing could be more objectionable than a road in such a state, and he could mention many similar instances. It was plain that the duty of the Engineer was to arrange his road in such a manner, that the deflection should be as nearly as practicable identical throughout, because if it greatly varied a rolling and pitching motion must be imparted to the trains. Uniformity of deflection was all that was necessary.

With regard to the Inspectors of the Board of Trade, with whom he had frequently been brought into contact, he begged to say, that, although he could not always agree with them in opinion, he believed, that they discharged their duties with candour and singleness of purpose. They had difficult tasks to undertake, as they had to commence their duties without any previous knowledge in the conduct of railways; and it was to be regretted that after remaining in the office just long enough to acquire a certain amount of information and experience on the subject, they were superseded by others. That, no doubt, accounted for some discrepancies between Civil Engineers and those officers; but he had always experienced from them gentlemanly courtesy, and, although they had sometimes differed from him in opinion, he never had occasion to call in question their integrity, or their honour.

April 8 and 15, 1862.

JOHN HAWKSHAW, President,
in the Chair.

The discussion upon the Papers Nos. 1,059 and 1,067 on "Railway Accidents," by Mr. J. Brunlees and Captain Douglas Galton, was continued throughout both evenings, to the exclusion of any other subject.

In pursuance of the notice on the card of the Meetings, on April 15th it was proposed, and resolved unanimously:—

"That in order to insure a fuller attendance of Members than could be obtained on Easter Tuesday, the Meeting be adjourned until Tuesday evening, the 29th of April."

April 29, 1862.

JOHN HAWKSHAW, President,
in the Chair.

No. 1,065.—"On the Sea Dykes of Schleswig and Holstein, and on Reclaiming Land from the Sea."[1] By JOHN PATON, M. Inst. C.E.

DURING the professional engagements of the Author in Denmark, for several years, he became familiarized with some of the principal features of the country, and collected such information regarding the Sea Dykes, as he considered might be of practical utility. He examined the shores of Schleswig and Holstein, and also the line of the coast of the Jutland Peninsula. His present object, however, is not merely to give a description of the dykes, which enclose some of the richest and most productive lands in Europe, but to draw attention to the vast importance of reclamations from the sea. The surface of marsh lands actually recovered and protected by the dykes is about 900,000 acres,[2] a reclaimed district far greater than exists in any other part of Europe—probably in the world—occupying an area as large as the Bedford Level and the Great Fens of Holland combined.

Denmark is singularly interesting to Englishmen, for the enterprising spirit and energy which distinguish the people were, in a great measure, derived from the ancient Scandinavians; and, independently of their conquests and discoveries, led to the construction of works of practical utility, which can be examined with advantage and satisfaction at the present day. Even in the fifth century, the renowned Vikings were a great seafaring people. They are said to have discovered America five hundred years before Columbus crossed the Atlantic;[3] they constructed sea dykes and reclaimed—although imperfectly—thousands of acres of land from the sea; they built the famous "Danneverke"[1] (a rampart wall constructed for the purpose of defending Schleswig, or South Jutland, from German invasion), which, for more than a thousand years, has stood the test of time, resisted the armies of Germany, and actually served the same purpose in 1850, which it did in the ninth century. Conquerors they were in a double sense, and of a far greater enemy than man; for while they visited with terrible retribution the invaders of their shores, they were endeavouring to restrain the ravages of the ocean. Denmark was then a wild inhospitable shore, described by Tacitus as covered with the gloom of forests, and deformed with wide extended marshes. And though it is generally supposed that such districts, with their humid soils, are bad incentives to enterprise and vigour, yet it is scarcely possible to find, among the vestiges of the past, engineering works more remarkable for their solidity and durability, or which have been more generally advantageous. These facts are the more extraordinary, when taken into consideration in connection with the changes to which these coasts have been subjected,[2] and the commercial importance of the navigation of the North Sea, the amount of shipping frequenting it being probably greater than in any other part of Europe.

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[1] The discussion on this Paper was taken in conjunction with the two following ones on a similar subject, by Mr. Oldham and Mr. Muller, and was continued over portions of three evenings, but an abstract of the whole is given consecutively.

[2] "The area of the marsh is stated at 65 square miles" (Danish).—Trapp's Stats. Kalender, 1861, page 4.

[3] Rev. Abner Morse on "Traces of Ancient Northmen in America with Geological Evidences of the location of their 'Vineland,'" Boston, 1861; also other writers, viz., "Discovery of America by the Northmen" (Beamish, 1841).

Respecting the tracts of land which have disappeared, Mr. Trapp (whose name is so well known in Denmark) says,[3] "It is well understood, that the changes in the relations between land and sea, which were earlier supposed to be caused by a regular increase or decrease of land, is now, according to more modern observations, considered to be derived not from changes in the volume of water on the earth, but from movements in the firm crust of the earth itself." The upheaving of the land, therefore, corresponding with what has been called a decrease of water, and the subsidence with encroachments or increase of water,—both of which movements have occurred extensively on the coasts of Denmark,—have had an essential influence on the geographical features of the country. Mr. Trapp shows the line of demarkation between the elevation and depression of the land to be north and south of a line drawn from the Nissum Fiord to Nyborg in Fynen (Plate 16); and further alludes to many places where the old beach is lying far above the point where the waves can now reach, strata of shells showing they have been undisturbed since they were deposited by the sea, creeks transformed into fresh-water lakes, and places that are called islands (or holms) perfectly land-locked; all which signs show that Denmark participates in the great Scandinavian rising which he assumes to be at the rate of one foot in a century, although it does not extend over the whole country. On the south of this line of demarkation, there would appear to have been no alteration which would indicate general depression of the land for many centuries; and, a gradual sinking, as contrasted with the rise in Northern Scandinavia, cannot be traced. On the Island of Römö there is an old Viking harbour, which Professor Forchhammer states, has been known not to have undergone any variation for many centuries. Although now separated from the sea by a marshy alluvial plain, it is evident that no material elevation of the surface has taken place. The alteration of the coast line—which has occurred principally in Schleswig—is a much older phenomenon, since this harbour lies on the east side of the island, which owes its insular nature to a separation from the main land, and of course the harbour must be posterior to the separation.

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[1] *Vide* Appendix No. 2, page 448.

[2] *Vide* Appendix No. 1, page 448.

[3] Trapp's "Statistisk and Topographisk Beskriwelse."

Although there has not been any general depression, yet it is evident that a great part of the west coast has, for centuries, been yielding either to the force of the ocean, or to some other powerful influences, which the natural barriers have not been able to withstand. The land has been overwhelmed, rich and populous districts protected by dunes, and sometimes even with costly dykes, have been destroyed, and the face of the country entirely changed. It is worthy of remark, that the remaining portions of land left by the inundations, gradually formed together again, where the tide came in slowly, and consequently, by a rapid deposit of sediment taking place, some of the 'halligs' (small islands not embanked) became connected with the main land and were enclosed, but were afterwards totally washed away.

In order to appreciate the peculiarities and importance of dyke construction in Denmark, the Author has considered it necessary, that some of the most prominent features of the coasts should be pointed out. With this object in view, he has collected from the principal Danish authorities, accounts of the chief storms which have occurred on the Jutland coasts during the last two thousand years,[1] and which will be referred to in the course of the following observations. The form of the coast at three different periods, together with other testimony, indicates that the old boundary of the main land of Schleswig has been outside the present islands. The present collective area of these islands amounts to 160 square miles, whereas, when they were connected, they comprised an area of 1,200 or 1,500 square miles, now overflowed by the sea, but formerly covered with fertile fields, houses, and churches, and inhabited by a thriving peasantry. The present form of coast has probably existed since the great storm flood of 1643. Although it is probable that the traditional map of North Friesland, extracted from Danckwerth

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[1] *Vide* Appendix No. 3, page 449.

(Plate 15), represents the character of the country two, or three centuries before the Christian era, yet for a period long antecedent to that time it must have been in the same state;[1] for not only are vast submarine forests known to exist, but also submarine tumuli, —ancient burial places, in which stone and flint weapons have been found within the last few years, identical with a period when neither iron nor bronze was known,—assigned by Professor Worsaae, in his Primeval Antiquities of Denmark, to an age from three to four thousand years ago.[2] Almost everywhere on the coast, under the present surface of the sea, remains of these forests may be traced, with their roots still spreading in the ground. On the west side of the island of Sylt (Plate 16), and at many other places, submarine bogs are found, in which are distinguishable the fen plants of fresh water, together with trunks of trees and branches of the birch tree. All the plants found in these mosses, or forests, are fresh-water, or land plants. These peat bogs are diffusely spread over the coast, covered sometimes by the sea to the depth of 12 feet.[3]

It is stated by Mr. Trapp, that these signs of land, so situated, are not confined to the west coast of Schleswig and the Marshes, but "are observable in Jutland, on the west side of Nissum Fiord, and on the east side of Mariager Fiord; also in Zealand, near Isefiorden, where a fresh-water peat bog is covered with a layer of blue clay, containing shells. They are also further observed on the south-west side of Bornholm, where large fir trunks lie fastened at the bottom of the sea, in a depth of several fathoms below the surface."

It is quite clear, from the observations on these shores, that although there has been a violent and sudden depression of the coast, probably about two thousand years ago, nothing of the kind has occurred for a number of centuries due to general causes. But it is beyond all doubt, that there is a subsidence, originating partly from the swampy peat mosses below the marshes being compressed, from several causes, and partly on account of the water on which the marsh rests, being slowly filtered through the soil which surrounds it.

It appears from the investigations and researches of Professor Forchhammer, (to whom the Author is indebted for valuable information,) that a great part of the marsh lands rests on peat mosses, some being firm,[1] where they happen not to be heavily pressed by the weight of the marsh, and others on water containing peat, which continue to sink until far below the level of the sea. This is known to be the case in the Wilster and Cremper marshes, in Holstein. (Plate 16.) They are still gradually, but slowly, subsiding, and they probably cover an area of 20 square miles. Now as these marshes are illustrative of what the Author believes to have occurred extensively on these coasts, as also in other places, he will briefly allude to the following facts:—A boring having been made, for the purpose of testing the nature of the ground, the rod, after passing through a trifling deposit of loam and a few feet of peat bog, suddenly dropped 16 feet; and immediately a stream of gas rushed upwards, which, on being ignited, burned for several days[2]. Other investigations were then made, and it was proved, that the marsh rested simply on a bed of water. In fact, it was a floating peat moss. This, however, was not the only curious feature; for during the storm in the North Sea in 1825, when the tide rose to a great height, and nearly approached to the top of the dykes, a number of salt-water springs burst forth from the marsh, and spread consternation among the inhabitants. Fortunately, the water fell as suddenly as it rose, and the marshes were thus saved from utter annihilation, from which they had only a narrow escape.

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[1] "The European races in the earliest period held the same relative situations as the tribes descended from them still continue to occupy."—Pritchard's "Origin of the Celtic Nations and Physical History of Mankind."

[2] In the neighbourhood of Husum, in a tumulus covered by the sea, were found by Mr. Grove, (a gentleman well known in the neighbourhood) flint knives, weapons and other fragments. It was covered by a submarine peat bog, and was precisely similar to the other tumuli of the stone period, which lie scattered along the land.

[3] Similar peat mosses are found under the marshes in Holstein, Hanover, Holland, and the east coast of England.

For a long period these districts were a source of anxious solicitude to the inhabitants and to the Danish Government, and no exertion, or expense, was spared to remedy the formidable and threatening evil arising from these peculiarities. Thousands of cubic yards of stone were thrown into the Elbe, (Plate 17, figs. 7, 15, 16, and 17,) at the point where the current impinged most strongly against the bank, and where there is a depth of 90 feet of water at spring tide, with a current of 8 feet per second. After considerable difficulty, the objects sought to be accomplished by these operations were obtained, and the current was diverted to the Hanoverian side of the river; thus modifying, at all events, one threatening evil, but still not removing the chief cause for anxiety, which appeared to be beyond human agency. Somewhat similar peculiarities were noticed in a district of the Eiderstedt, on the north bank of the Eider. (Plate 16.) The water in many of the wells, during the great flood, rose to an extraordinary height, and in other places several feet above the ground. But, although it was remarked that the water was not salt, there is little doubt that this phenomenon would have occurred had the pressure continued. The marsh, however, although resting on peat bog, is more solidified, and is consequently less liable to permeation and an eruption of the sea, than the one previously alluded to. It is no uncommon occurrence for the dykes, in consequence of their weight, to exercise a great local pressure, causing a more rapid sinking than in other parts of the marshes.

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[1] Other large tracts, which rest on old sea-sand, do not sink any more.

[2] Forchhammer.

These facts are important, because they, together with the curious storm floods which will be afterwards alluded to, afford the means of accounting for the tremendous disasters recorded, and which have been hitherto attributed to the bursting through of the protecting lands, or dykes, but which in reality may have had, and in several of the most important instances can be shown to have had, nothing whatever to do with them. This, it is believed, can be confirmed by that remarkable case, the formation of the Zuyder Zee, the site of which was originally a tract of fertile land of nearly two millions of acres,[1] covered by towns and villages, although in reality it was only a marsh resting on peat moss. This occurred, according to popular belief, by the bursting through of the isthmus between Steveren and Medemblick; but there is reason to believe the destruction of the isthmus was the effect, and not the cause, of that great eruption. It would appear to be a case precisely similar to that which has been stated with regard to the Holstein marshes; for only the year previously to the disaster, salt-water fish were found in the wells of the district, thus proving their immediate connection with the North Sea, and on this discovery some of the people left the country. The pressure consequent on the sudden and great elevation of the water in the North Sea was greater than the marsh was able to withstand, and the eruption from below overflowed and destroyed it, the isthmus then giving way as a necessary consequence.

It is quite possible, that other similar disasters in Holland, such as those resulting in the formation of the Bies Bosch and the Dollart,[2]—the former stated to have been formed in 1421, when seventy-two villages were destroyed by the bursting of a dyke,—may have had their origin in a like cause. The Author believes that wherever any serious breach has occurred in a main dyke, either in Schleswig, or in Holstein, it has rarely been by the direct action of the sea on the outward face, but rather on the inner slope, the waves rolling over the top and undermining the foot. Other circumstances of a similar nature, but on a vastly extended scale, to those above alluded to, have no doubt operated in the variation of the Peninsula, indicated between the period of its traditional state and the time of the Waldemars in 1240.

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[1] A small lake formerly occupied the centre of this district.—"Encyclopædia Britannica." Eighth Edition. Vol. xi. p. 581.

[2] *Vide* Appendix No. 3, A.D. 1277 and A.D. 1243, Dollart.

Independently of the two great phenomena,—the general subsidence of the southern portion of the Peninsula, no longer operating, and the gradual elevation of the northern portion of Scandinavia, including Norway and Sweden, still progressing,—other local peculiarities appear to have exercised considerable influence on the features of the country. Thus, for instance, the Island of Amrom is stated to have risen 20 feet from the earliest recorded flood. Features almost identical with these may likewise be traced in other great marsh districts. In Mr. Jackson's Paper on "The Engineering of the Rhine," it is stated that "the coast of Holland is continually changing, in a greater, or less degree, and during the sixteenth and seventeenth centuries it rose to the extent of 20 feet."[1] It is also well known that in the fens of Lincolnshire, which are for the most part below the level of the sea, vast peat bogs lie buried.

By comparing the catastrophe called the Cimbrian Flood, with those of later date, and especially with the last great storm of 1825, it has been ascertained to have reached about double the height of the greatest storm floods known in history. Professor Forchhammer states, that the difference between the height of the Cimbrian Flood, and the present daily water level, is 40 feet (Danish), or 41·3 feet (English); but he attributes this great elevation of the sea to some extraordinary and once-occurring agency. He states that "spring tides and strong westerly gales cannot explain such a height of flood; even if we have recourse to Plutonic movements of the bottom of the sea, we must imagine them to be infinitely stronger, in order to explain these floods by means of them." The upheaving of the Island of Amrom, after the general subsidence of large portions of the peninsula, does not appear to have been participated in by any of the other islands in the North Sea; at least, there are no positive traces of it, and, indeed, referring to the ancient map of Heligoland, a contrary result is observable. It is well known, that the area of that island was much greater in earlier ages. Thus, in the eighth century, it is stated to have been a thousand times larger than it is at present. It is certain that in the year 1216 a great storm flood devastated all the marsh lands, and that Heligoland lost so much, that although, in 1030, there were nine parishes, but two remained after the great catastrophe.[2] The White Cliff has been destroyed within a recent period. By comparing these records of storm floods with the maps of 1240 and 1860, (Plate 16,) the evidence and opinions of scientific men in the north of Europe, and the traditional map of Friesland, (Plate 15,) there can be little doubt that those shores have witnessed, within a comparatively recent period, most singular variations, a correct knowledge of which is of great importance in the design and construction of the dyke works.

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[1] *Vide* Minutes of Proceedings Inst. C.E., vol. vii., p. 237.

[2] *Vide* Appendix No. 3, page 449.

Although in many places an encroachment may take place on the land, by the sea washing away the shores and cliffs, yet it is limited in extent. Tetens says, that more marsh land has been restored since the embankments have been made than has been washed away; for not only are the inner marshes always lower than the outer, but the foreshore seems to be continually increasing. Besides this, it has been found, that many of the sluices now lie much too high, (thereby showing gradual relative depression of the land,) and consequently that they are incapable of taking off the land water. The marsh soil in Eiderstedt has certainly not decreased since dykes were introduced.[1]

Amid all the changes which have occurred on these coasts, there would appear to have been no considerable variation—certainly since the time of Waldemar,—more than 600 years ago,—in the channel at the Lyster Deep; and probably even from the most remote ages, it has continued to be the deep inlet on the western side of the Peninsula. It now forms the only inlet, where a vessel of even ordinary size can enter. From the Eider to the Skaw, it is the only place, on this most dangerous and inhospitable coast—beset with sand banks stretching far out to sea—which could be made available as a harbour. This is the more remarkable, as all the drainage of the country falls to the westward, the deep fiords being on the eastern side. The entrance to the Liimfiord (an arm of the Baltic) at the Agger channel is gradually filling up with sand, and will only admit vessels drawing 5 feet of water. This opening to the North Sea was formed by the great storm of 1825, making an island of the northern part of Jutland; there was then a depth of 10 feet of water. The spit of land separating the North Sea from the Baltic is recorded to have been in existence for about a thousand years—previously to its being broken through, on the night between the 3rd and 4th February of that year, by a storm from the south-west.[2] It is stated by Mr. Juel, in the "Slesvigs Provindcials Efterretninger," that the five great floods, in which upwards of thirty thousand persons perished, scarcely equalled it, either in the height of the water, or in the grinding and rolling motion of the waves. The most singular feature, however, about this flood was, that although there had been a number of storms of less violence during the winter, which had blown off tiles in the towns and unroofed the houses in the country, not a single tile was knocked down, or a thatch disturbed.[1] Though the wind is reported not to have been stronger than could have been expected with a flood of 4 feet over ordinary level, the water in the wells rose 6 feet, and sprang several feet high out of great holes in the marshes; while at the highest floods of 1791-94 and 1803, it stood on the east sides of the islands of Sylt, Fohr, and Pelworm at 10 feet above the ordinary height, this storm flood was 16 to 17 feet, and in some places in Holstein even 20 feet above the ordinary level. It is stated to have risen so rapidly, that at Simonsberg, it reached a height of 15 feet in one hour, and afterwards rose still higher. In the Eiderstedt the flood lasted an incredibly short time, and the water fell with equal rapidity.

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[1] Suderstrand, an Island about half the size of the present Eiderstedt, consisting principally of Dunes, in existence in the thirteenth century, is entirely gone. No doubt in the fearful flood of 1362, it met the same fate as Nordstraud in 1634, when the greater part of that Island was destroyed.

[2] This same storm seems to have equally affected the coast of Holland, covering with water an area of upwards of 300,000 acres, and doing immense damage. It is also stated, that a dyke constructed of masonry gave way, whereas other portions formed of fascine work were not injured. (*Vide* Mr. Jackson's Paper on the "Great North Holland Canal." Minutes of Proceedings Inst. C.E., vol. vi. pp. 81-134.)

This singular flood, as well as others almost as remarkable, must be attributed to agencies different than those arising simply from the effects of the violent gales of the North Sea. No such gales could have produced the effects there noticed. These storms seem, undoubtedly, to have been connected with earthquakes, or volcanic movements of the bottom of the sea, and the phenomena which were observed during, or immediately after the earthquake in Jutland, in 1841, corroborates this opinion. It will be impossible in this Paper, to do more than allude to these observations. It may, however, be noticed generally, that from the twelfth to the nineteenth century, no less than two hundred and fifty-two earthquakes occurred in the Scandinavian Peninsula and Iceland, the movements in the former being usually from S.W. to N.E., or almost invariably the direction in which the most disastrous storm floods have affected the Danish coasts.[2] At Agger the water is stated to have risen from 6 feet to 8 feet, and the rise was also distinctly perceivable in Trontheim Fiord. The islands (excepting Pelworm) suffered but little, owing probably to the circumstance of the protection afforded by the dunes, which extend along the west of Jutland, and in the direction of the old line of coast, passing through Fanö, Römö, Sylt, and Amrom. (Plate 16.) The Author has examined them on the latter islands, where they are upwards of 100 feet in height. They disappear at Amrom, and are again seen on the west coast of the Eiderstedt. The disappearance of the dunes between these places is probably owing to the washing away of the marshes on their eastern sides, which could not take place in the other islands, owing to the circumstance of the land being too high for the sea to overflow them. It may be remarked, that the sand is in places singularly productive in grasses, far more so than is usually supposed. One island in the Baltic, within the Author's own knowledge, (and where he is now engaged in reclaiming 12,000 acres from the sea,)[1] has frequently realized an annual rental of from £3 to £4 per acre, by the sale of the grass alone; although at that particular locality, there is a depth of from 6 feet to 10 feet of sand, which, however, has been levelled by occasional floods, being only separated from the sea shore by the low sand dunes.

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[1] *Vide* "Slesvigs Provindcials Efterretninger," p. 164.

[2] *Vide* "The Earthquake Catalogue of the British Association, with the Discussion, Curves, and Maps, etc. By R. and J. W. Mallet. 8vo. London. 1858."—During the great Earthquake of Lisbon, the sea was so much agitated along the coasts of Holland and Friesland, that vessels were dashed against each other and moorings broken, and shocks of Earthquakes and tremblings were felt in Denmark, Rendsborg, Elmshorn, and Meldorf. The wells and springs rose so high as nearly to inundate the land in places, and the River Eider was particularly agitated. Many other cases might be alluded to, showing disastrous inundations occurring on the low-lying coasts of Holland and Friesland, simultaneously with shocks of earthquakes in neighbouring localities.

In making excavations between the main land and the Lyster Deep, covered with 6 feet of water at high tide, the Author has found, beneath 1 foot or 2 feet of sand, immense masses of partially decomposed land plants, apparently in the position in which they grew. This fact in itself would prove the great fertility of these districts, and show that although vegetation has seemingly perished, it has left extensive traces behind, which may ultimately enter once more into important usefulness when the district is reclaimed.[2]

Without entering into further particulars of the peculiarity of the coasts, it is now proposed to call attention to the details of the construction of the dykes. (Plate 17.) The construction of dykes on the coast of Denmark is of great antiquity, since Römö, Sylt, and Amrom had them in the earliest periods. They are not only mentioned by Saxo Grammaticus, but in much earlier records. Thus in the storm flood of 1075, the dykes, which certainly in those days were the now existing summer dykes, are alluded to as having been broken through. The North Frisians had them in 734, when Charlemagne attacked their southern kindred in Holstein, for they called their country 'Spadeland,' because the spade was so much used, as well for tilling the ground as for protecting the dykes, which they endeavoured to strengthen after each destructive flood. These dykes were also used as a means of defence; for the country, with its watercourses and channels, was a wild and almost impassable labyrinth, to those unacquainted with its intricacies. The early dykes were not, however, for regular enclosures, which were only fully developed in Denmark in the tenth century, and the larger enclosures in the fifteenth century, but constituted only slight protective works.

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[1] This work has been executed under the Author's direction as Engineer, by Mr. J. R. Allen, of Preston; the pumping engines being supplied by Messrs. Galloway, of Manchester.

[2] Mr. Trapp states, that the levelled district from the Flyve sand on the west coast gives also good crops of grain, and he attributes this fertility to the fact of its intermixture with mica particles, which appear as regularly in the Flyve Sand as in the marsh clay. The sand also contains Titanic iron, and great quantities of amber, which are being continually cast up on the western shores.

The present 'Halligs'—the remnants of large tracts of land—are instructive as to the earliest plans adopted for sea embanking. They are inhabited, but are only used as pasture lands, being subject to frequent inundations, and not being more than 2 feet or 3 feet above the ordinary flood level. In early days, ditches were dug in the marshes, and mounds were formed in the centre, upon which the residences were erected, and round which the tide continually flowed. Thus the dweller on the 'Hallig' had only this little mound and the strength of his house to depend upon for his security. Any one travelling through the Eiderstedt may notice this peculiarity in the marshes even at the present day. These little elevated spots were called 'Warfths;' and by degrees, as the land became cultivated, the dykes were extended until whole districts denominated 'Koogs' (in Holland 'polders') were enclosed, and the country assumed the rich appearance it now bears. It may be remarked, that the preservation of these 'Halligs' and 'Islands' is of vital importance to the whole of the Schleswig marsh lands, for it is certain, that if they ceased to exist, a vast extent of main land dykes would require to be reconstructed. The sea, now broken by the islands, would then expend its full force on the main land, and what is worse, the forelands, now forming so rapidly, would be destroyed, which are at the present moment so essential to the safety of the dykes. It is a curious fact, that while the forelands are forming, the 'Halligs' are rapidly decreasing, so that the beneficial influence they exercise will cease with time. It is even stated, that there is a loss of 4 feet yearly of the edge of the beach.[1] The works, however, now being carried out will ultimately stop this destruction.

The Island of Pelworm possesses, in its isolated position, a vast influence on the maintenance of the marsh districts, notwithstanding all the strange vicissitudes it has experienced. It is supposed, by some people, that it will inevitably disappear in the course of time; but the Author is of opinion, that it ought to be secured from such a fate at almost any expenditure of money, not only because of the intrinsic value of the island itself, but on account of its importance as an advanced protection to the Schleswig coasts. The dykes on Pelworm, as also on the other islands, are not so high as on the main land, owing to the circumstance of the tides not rising to the same extent, as where the current is completely stopped, and where the breaking of the waves is more dangerous. The nature of the soil would also appear to be the great difficulty with regard to this island, and renders the utmost caution, combined with the soundest skill and judgment, requisite. It is below ordinary flood level, is gradually sinking[1] like other enclosed lands, contains layers of peat, which not having as yet become sufficiently compressed, are unable to withstand the pressure resting on them, and thus the island will continue slowly to subside, as it has done for centuries, until this compression is accomplished, unless the intervening space between the main land be enclosed. It is therefore a question of moment, whether the strong and perfect stone dykes, extending 6 miles in length, will absolutely free Pelworm from danger.[2]

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[1] In the year 1713 the 'Halligs' paid taxes for 8,056 Tönder, while the taxable area in 1778 was reduced to 4,980 Tönder, showing a decrease in 65 years of about one half the area.—BRUUN.

On the 'Hallig' of Nordstrandischmoor, which previously to the storm flood of 1634 formed part of Nordstrand Island, the layers of peat were covered, close to the surface, with a deposit of loam and soil.

The dykes in the two districts of Ditmarsh and Eiderstedt, the former in Holstein, the latter in Schleswig, or South Jutland, may be classified as summer dykes, inside dykes, and outside, or sea dykes. The summer dykes are the most ancient, and seldom exceed 8 feet in height. They are built far inland from the present line of coast, and were constructed by the early settlers on the 'Warfths,' as a protection against occasional tempests. They are now almost superfluous, but serve as an additional security, in case of the sea dykes giving way. They also, like many of the other dykes, afford the means of communication between the different 'Koogs,' a roadway being formed on the crest. The districts are now divided into what are called 'Deichbands,' that is, an Association of a number of 'Koogs,' for the maintenance of the sea dykes, to which each proprietor contributes his quota, according to the situation and the advantages afforded to his property. The inside dykes formed, originally, the sea dykes, and vary in height from 8 feet to 10 feet over ordinary high water. Like the summer dykes, they were for a long series of years the only means of protection to the country. In the Rivers Eider[1] and Elbe, and on the coasts which are subject to the tides, and to considerable variation on account of the winds, the sea dykes are of a more permanent construction than in the rivers where no tide occurs, and the elevation of the water arises from continuous land floods, occurring perhaps but once, or twice in the year. A considerable portion of the River Eider has been embanked, extending for many miles from the sea nearly as far as Rendsburg.[1] It had originally two outlets to the sea, and formed a junction with the Rivers Hever and Treene.

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[1] "In Pelworm, a greater or quicker sinking has shown itself during the last century; for this part of the marsh was formerly the highest, as the 'Hallig Hoog' is still the highest 'Hallig.'—Bruun, Marsch Oër, p. 35."

[2] The extensive 'watts,' or spaces between high and low water, on the west of this Island, having no protection, consist entirely of sand, where little vegetation can strike. The stone dykes at Pelworm have already stood the ravages of the sea undamaged for ten years.

The dykes are erected at various heights, along certain parts of the coast, according to local circumstances; an excessive height being found undesirable. As a general rule, the highest known flood level is taken as a point of departure, and the height of the wave is then added. As, however, the height of the outer ground, called 'watt,' being the space between high and low water, has a considerable influence on the height of the wave, the following normal sections have been considered by Captain Carstensen, the Dyke Inspector in Schleswig, to meet the requirements in his district:—

		Feet, Danish.
1st.	For exposed situations, with low outer ground	18
2nd.	Ditto, with higher outer ground, or less exposed with low outer ground	17
3rd.	Unexposed, with high outer ground .	14, 15, 16

One of the chief considerations in the first formation of the dyke is the space requisite for the cess, as the dykes are necessarily so high that they cannot have one slope on the outward side. Generally, in Schleswig, (Plate 17, fig. 1,) a slope of 3 to 1 from the top is used to a height of 10 feet or 12 feet over ordinary flood, finishing with a cess of 8, 10, 12, or 15 to 1 according to circumstances. The section is, therefore, entirely relative to the position which it occupies, the extent of the foreland, its height above ordinary water level, and its exposure to the direct action of the waves and wind. Thus, in illustration, the dykes on the Islands and the Elbe, may be compared with those on the mainland of Schleswig. The variations in the height of the water on the coast and other peculiarities, render modifications in the profiles necessary.

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[1] This river is navigable for vessels drawing 10 feet of water as far as Rendsburg, and its length to the Baltic being only 90 miles, it reduces the dangerous passage round the Skaw nearly 900 miles, and has been of great importance to the trading interests of the country. In Schleswig generally the tide recedes from 4 to 11 feet below ordinary flood,—at Husum, Friedrichstadt, and Tonning about 9 feet, and at the Islands 10 feet. At Rendsburg the difference between high and low water is 2½ feet, with moderate winds.

Even the same dyke has often a different section. During some of the great storm floods, the water rose to a height of 14 feet on the sheltered parts of the Holstein dykes; while in others, scarcely more than a mile distant, it was 20 feet above the ordinary level, and rushed over the top of the dykes with considerable force. At Meldorf, with a south-western wind blowing right on the land, before which there is a broad foreland, the water rose only 8 feet to 9 feet above ordinary level; while at Brunsbuttle, on the Elbe, it was upwards of 14 feet; and again, scarcely three-quarters of a mile distant—where the water was sheltered from the wind—not more than 8 feet. The variations in the rise of the water, (which appear to diminish northward,) on the Jutland coast, are equally remarkable on the Baltic side, but as is well known, they are due entirely to the winds.[1] These facts will show the importance of local peculiarities, which would appear not to exist on the coast of Holland, or probably in any other part of Europe, and of which the later constructors of these important works have not failed to avail themselves, rather than depending entirely on theoretical considerations. The width of the top, in the smaller dykes, is from 8 feet to 10 feet, and in the larger ones, from 10 feet to 20 feet. The crests, as previously stated, are used as roads, sloping on one, or both sides to allow the water to drain off: indeed the breadth of the top depends, in a great measure, on whether the dyke is to be used for a road, or not. Although a high level for the crown is of much importance, and some dykes have been made higher since 1825, it is not always desirable, as for example in the Island of Pelworm. The dykes have, almost universally, flat slopes on the seaward side, on which their strength and security depend; and although this increases the cost of the work, it is undoubtedly preferable to incur this additional expense in the outset, rather than to risk the construction of a weaker form; still there are limits which both slopes should not exceed. Generally the inner slopes of the dykes have an inclination of 1½ to 1. The outer, or sea slopes vary considerably, being in the Eider and the Elbe sometimes 3 to 1, but where they are exposed to the sea 6 to 1, and even more, according to local circumstances. Thus in illustration, attention may be called to the curved sea slopes of the Pelworm dykes, the Friedrichenkoog dykes, the King Fred. VII. Koog, and the dykes at Kronprindzen Koog and Brunsbuttle, (Plate 17, figs. 12, 13, and 14), in Holstein, four, or five of the best and strongest forms of construction, and which are peculiarly adapted to their respective localities. It must be observed that the stone facing is considered by some, a dangerous mode of defending the dyke, as it prevents the natural rising of the ground, causes a depression at the foot of the facing, and is very expensive. Its application, on a large scale, is only justified under peculiar circumstances, by the want of straw, and by the scarcity of labour in case of danger. In exposed localities, these convex dykes are highly important. The height is taken at 4 feet over ordinary flood, and the projection of the stone, say three times the height above the outer ground, with a cess, or grass slope forming a tangent to the circle.

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[1] *Vide* Appendix No. 1, page 118.

In fixing the width of the top and the inclination of the dyke, due consideration has to be given, not only to its position, but also to the quality of the material to be used, which consists sometimes of clay, and at others of moor, or bog earth. It is usual for the dimensions of the dyke to be enlarged, or reduced accordingly; and where it has to be built on a place still covered with trees, they are removed, and the ground is cut up, so as to form a complete junction with the new embankment. The best material which can be used for the dykes is clay, mixed with sand; and as the marsh ground itself is usually of this nature, it is generally used. Clay alone, without intermixture with sand, easily bursts after exposure to the rains, or dries suddenly by excessive heat. Common soil is frequently used, and is considered good, though not equal to the sandy clay, as moles, rats, and foxes can more readily make passages through it, which at high water may sometimes become dangerous, and the holes are not easily stopped. Where good materials cannot be procured, in sufficient quantities, for the formation of the dyke, it is customary to cover the water slope with clay, several feet in thickness; and if the material is of fine sand, or of bog earth, both slopes are covered with clay. In other cases, also, where dykes are made of sand, or earth, it is necessary to fill up the interior with clay, laid a considerable depth in the ground, as experience has shown that the water will, without this precaution, sometimes find its way through the ground, and issue behind the dyke.

Respecting the formation of the dyke itself, this usually corresponds with the work at ordinary embankments, excepting that in filling up for the dyke, it is desirable to keep the earth parallel with the outer slope, filling in with those portions from the inner side of the bank. When this is done, and the works are sufficiently solidified, the slopes are covered with grass sods, 6 inches thick, and one foot square, which form an important feature in the Schleswig dykes, and every care is taken to improve the growth of this grass, no plants or trees being allowed on the banks. Indeed over the level of ordinary flood, grass sods are nearly always used, either uncovered, or covered, with straw matting, and in exposed places they are connected by straw bands.

In cases where excavations have been made for materials for the bank between the dyke and the sea, they are not cut in a direction parallel with the current, or in connection with one another, small banks being left between the excavations, to prevent the formation of a stream from a sudden influx of water. Wherever suitable earth is to be had outside the dykes, it is always taken, but where circumstances require it to be used from the inside, it is only done with extreme care, a breadth for the berm, or cess, of 50 feet to 80 feet being left.

Where every ordinary tide reaches the foot of the dyke, and there is a low exposed 'watt' or outer ground, the works comprise—

1st. Pitching the sea slope with stone.

2nd. Pitching only the foot of the dyke, and increasing the slope.

3rd. Covering the sea face with straw matting.

4th. Protecting the dyke with fascine and hurdle works.

All these plans have been carried out with uniform advantage, under the circumstances in which they have been applied. Of course the best protection which can be afforded to the foot of the dyke, is a good foreland lying on its seaward side, and the probability of damage decreases with the height of this foreland. Where, however, there is deep water, this cannot be obtained, and the breaking of the waves is not only increased, but the dyke is exposed for a longer period to their operation. Everything which can tend towards the increase of foreland seems to be adopted as the surest course; such as groynes, coverings of straw and brushwood, &c., by which the expense of covering with stone is reduced. There is no feature of greater importance in connection with the dykes than the projecting works, or groynes. Where they are short and low, although they prevent the outer ground from being hollowed out, they do not cause any raising of it. It has been found, that where they have a height of 2 feet above ordinary flood, with a length of 1,300 feet to 1,700 feet, they afford practical protection to the dykes, as they cause the outer ground to rise considerably, and they are indeed quite indispensable. Where the object is rapidly to increase the alluvium, they are constructed with the following section:—Height, 2 feet to 5 feet; width at the top, 4 feet; with slopes of 4 to 1 on the west, and of 3 to 1 on the east sides. The earth work is rounded off so as to increase the section, and is covered with grass sods and straw matting. Some of these works have been constructed of great length, one of 7,689 feet (Plate 16, General Plan), with the object of ultimately connecting the Hamborger Hallig with the main land.

In the first instance, above alluded to, of pitching with stone, the sea slope is covered with a layer of clay and small stones, about 1 foot in thickness, on which are packed stone blocks of at least 300 lbs. weight, the smallest section of the stones lying uppermost. When constructed on sound ground, this form is almost imperishable, and affords a complete resistance to the greatest storm floods, and also receives but little damage from the ice thrown against it in the winter.[1]

Much steeper slopes are used with the solid form; generally an inclination of 2 or 3 to 1 may be adopted. The pitching is carried to a height of from 12 feet to 16 feet above ordinary flood. Where the stones are procured with difficulty, or in cases where the ground may not be equally favourable, the curved form is used, or the foot of the dyke only is covered, as mentioned in the second case. Here the slope is lengthened, and assumes the general character of the dykes having a considerable foreland. It answers well under certain conditions, naturally not causing so great a depression at the foot as with the stone-faced dykes.

In the third case,—protecting the slopes with twisted straw bands,—it has been found, that although they have some disadvantages, particularly as regards their durability, they are considered in the end most generally advantageous. They are used, first in urgent circumstances, such as in winter, or where loss of time would increase the danger, or the loss of earth; secondly, when grass sods are not to be procured, and the material is clay, or sand with a considerable portion of clay; and thirdly, to repair all damages under ordinary flood. In all cases where the earth is not covered with grass, the straw must be spread over as thickly as possible. The rye, or wheat straw, 2 inches or 3 inches thick, is fastened to the earth, with straw bands, formed during the work, by stitching down, perpendicular to the spread straw, the one end of a portion of the straw about 1 inch thick; the loose end is then turned round, and stitched down again, about the middle, into the dyke 6 inches or 9 inches; the number of the stitches is three, or four per foot in both directions. When there are four per foot, the distances between the straw bands are first made two to a foot, and then care is taken that the two new stitches come between the first. Other straw ropes are then fastened, and interwoven together, and the same operation is continued; the entire face of the dyke being sometimes covered in this way, the ropes being laid diagonally along the bank. As this straw matting can only be used with soft materials, it has to be renewed at least once a year, but generally twice, and very often three times. In the latter case, where the situation is exposed, the yearly expense is so considerable, that the construction of a stone dyke is preferred, and is considered more economical. The average cost, including work and materials, is 3 shillings for 256 Danish square feet, or about 1¼ penny per square yard English.

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[1] Colonel Christensen and Captain Irminger, officers of great ability, have proposed and carried out successfully considerable modifications of these stone slopes.

The fascines generally used, consist of brushwood bound together in bundles; the best are composed of willows. They have a length of about 10 feet, a middle thickness of 1 foot, and are bound as shown in Plate 17, figs. 9, 10, and 11. The mode of construction, for securing the foot of a dyke with these fascines, consists in several layers being placed one over the other, each row being covered with rough stones. In the direction A B (Fig. 10) they are laid close together, and bands, made of reeds, or willows, are then fixed to them by small stakes, which are driven into the ground. In the same manner the other layers are made and fixed to the first layer, and to the ground, to depths varying according to circumstances from 2 feet upwards, until the required height is obtained, it being customary to place four, or five layers, giving a height of 6 feet or 8 feet.

Another method of covering the slopes, and of protecting the foot, consists in laying fascines, with the butt ends at the foot of the slope, at distances of 1 foot 6 inches from each other; the brushwood is then divided, giving an equal thickness on the dyke of 6 inches. When this is done, strong willow bands of fascines are laid obliquely, at equal distances of 1 foot 6 inches, ascending from the foot of the slope, and are fixed by strong stakes into the dyke, the intervening spaces being filled up with stones.[1] The slope is sometimes covered with clay and gravel. Various other fascine, or bush works are adopted, suitable to the more exposed localities, as for example at Schehlenkuhlen, on the Elbe. (Plate 17, figs. 15, 16, and 17.)

The Author has found that sea weed, together with stones, has also been adopted on some of the dykes, and it has been strongly recommended by one of the Dyke Inspectors. He has used it himself in a sea embankment on the Island of Lolland. At Beitenburg, in Holstein, where a clay dyke was found to be sinking, on ground which was broken by the inundation of 1825, a dyke of hay was constructed by Colonel Christensen. In this way he succeeded completely in keeping the water from the marsh, and was enabled to construct a solid bank before the autumnal storms began.

Notwithstanding that all the modern dykes have been constructed with reference to the great storm flood of 1825, a combination of circumstances may arise, rendering it necessary to adopt additional means of security, at moments of emergency, and therefore, at certain exposed places, means of protection are at hand. Small stakes are driven into the dykes at distances of 4 feet apart, and planks are secured to these, the space between being filled in with earth. In another method, fascines are used in lieu of planks. In this manner a dyke can be easily and quickly raised 3 feet or 4 feet. Where fascines and planks are not easily procured, a number of stakes are driven into the dyke, and clay, brushwood, stones, and sand-bags are rammed between the spaces, and the heads of the stakes are then bound together. By these means a sudden danger has been more than once averted, and the districts have been saved from inundation.

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[1] It appears, from Mr. Jackson's Paper on "The Great North Holland Canal" (Minutes of Proceedings Inst. C.E., vol. vi., pp. 81–134), that fascine work somewhat similar in description to this is used in Holland.

According to the laws regulating the 'Deichbands,' all the inhabitants of the 'Koogs' have an interest in the protection and security of the main dyke, and contribute towards its maintenance, relatively to the position of their lands, their exposure to danger, and the intrinsic value of the soil. The Government at the same time exercises a controlling power through the Dyke Inspectors—always engineering officers of great skill and judgment, and whose lives are devoted to perfecting the works under their control.

In some instances, sluices have been a considerable hindrance to enclosures, several streams passing through the foreland, necessitating works of an extensive and costly nature. During the last few years, vast sums of money have been expended in these works (which can only realize a profit after years of labour), and most important projects are still being carried out. These beneficial changes are mainly due to their Excellencies M. Wolfhagen and the Holstein Ministers, and to the liberal and enlightened views of his Excellency M. Fenger, who has provided the ways and means for carrying out the works, and whose elevated mind and professional reputation are justly esteemed by his country. There are few cases, indeed, where the expenditure is not justifiable, more especially where such reclamations give additional security to the existing 'Koogs.' Thus, for instance, as in the foreland 'Friedrichen Koog,' lately enclosed from the designs and under the direction of Captain Carstensen, lying south of Hoyer (Plate 16, General Plan). This unites a most favourable situation and form, with a superior soil, and, besides affording the means of improving the drainage, it is found highly advantageous in financial respects. The height of the foreland was about 2 feet over ordinary flood level. The quay, or protecting dyke, erected previously to the construction of the main bank, and placed about 500 feet distant, was of great service, in enabling the work to be carried on with regularity and without interruption. It is sometimes carried to a height of 6 feet or 8 feet over ordinary floods, and is usually erected one year before the other. The area of this enclosure is 2,000 acres, and the total cost, including the stone sluices, (which amounted to

£17,000,) the roads, bridges, and ditches, has been about £48,000; the land realizing nearly £70 per acre, or an immediate annual rental of £3 per acre.

In concluding these remarks, the Author considers that the true test of successful engineering enterprises is not so much the perfection of the gigantic works which have been raised up as monuments of skill, but rather the benefits they have conferred upon mankind. If reclamations from the sea are judged by this standard, the advantages are incalculable, and it can be shown that even as they exist at the present moment,—although they require the closest practical and scientific attention,—no other engineering works are of more paramount importance, or have conferred greater benefits on the world.

By considering all the changing and chequered events of which Denmark has been the scene, for a lengthened period of 2,000 years; looking to the Danish coasts as they existed only 600 years ago; and remembering the small amount of scientific knowledge exercised in the enclosure of land at that time, it is impossible not to be impressed with the skill and judgment which have been manifested in the construction and completion of these works. From the earliest times the descendants of the great Vikings have gone on, amid difficulties and perils, year after year, century after century, with unabated zeal and untiring energy, adding to the security and extent of their lands, converting them from desolate tracts into rich and fruitful corn fields. They are, however, now well compensated for the troubles they have encountered during long ages of vicissitude. Originally a trackless waste, now some of the richest land in Europe marks the same locality, and, together with other parts of the kingdom of Denmark, furnishes corn to England, to an extent only surpassed by two other great states of the world. A surplus of about two million quarters of grain is exported from Denmark; the total production being about nine millions to ten millions of quarters annually. The two Duchies of Schleswig and Holstein supply three millions of this amount. By this excess of production over consumption, in a great measure owing to the reclaimed districts, the absence of all poverty in the country can be accounted for. In addition, however, to the grain crops, there are large numbers of horses, and upwards of 70,000 head of cattle and 150,000 sheep annually grazed and fattened on those fertile marshes, and most of them are exported for the English market.[1]

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[1] The total number of horned cattle in Denmark may certainly be calculated as from 1½ to 2 millions. In 1860, the horses in Denmark, Schleswig, and Holstein are stated at 600,000, and the sheep in the Duchies about 323,000. The grain exported from Schleswig and Holstein in 1855 was 643,075 quarters.—"Trapp's Statistics."

By comparing these results with those of other reclamations, and considering what might be derived from further extensions, an estimate may be formed of the probable results of reclamations from the sea in their most extended sense. If attention is confined, in the first instance, to the great reclamations termed the Bedford Level and the Lincolnshire Fens, although not nearly so exposed a country as Denmark, it is known that in early times the districts were almost as desolate as North Friesland, yet the level of the Fens now contains more than 600,000 acres of the richest land in England; and considering the comparatively short period (about 200 years) in which this has been accomplished, it is almost as marvellous as the Danish works, or as those in Holland, and is another forcible example illustrating the triumph of engineering skill over natural disadvantages. In the earliest times, that district was a dense forest, then it became a swamp, probably through some great subsidence, and was inundated by the sea in the thirteenth century, when so many disasters occurred on the Danish coast, and was first attempted to be reclaimed in the fifteenth century. Without venturing to calculate the advantages which have been already derived from these monuments of industry, or the benefits they have conferred on the country, it is believed that the present value of the Fen districts cannot be less than £50,000,000, while the annual yield of corn is enormous.

In Holland, vast reclamations have been effected contemporaneously with those in Schleswig, and works have been carried out there, which are estimated to have cost not less than £300,000,000, and to be by no means in excess of what is actually required. The area, however, of the marsh districts enclosed by the dykes is stated by Mr. Hyde Clarke, and in Dugdale's[1] 'Treatise on Embanking,' not to be so extensive as that of the English Fens.

Now, independently of the results from other enclosures, such as Romney Marsh, the earliest embanked district in England, and Haarlem Lake, each covering an area of 70,000 acres, the three cases mentioned have an area of more than 2,000,000 acres, representing an annual revenue of about £8,000,000 sterling, a sum equivalent to more than the net passenger receipts of all the railways in the United Kingdom, and they are probably capable of affording a larger supply of grain than is now imported from America, Russia, and Prussia combined. It has been estimated by

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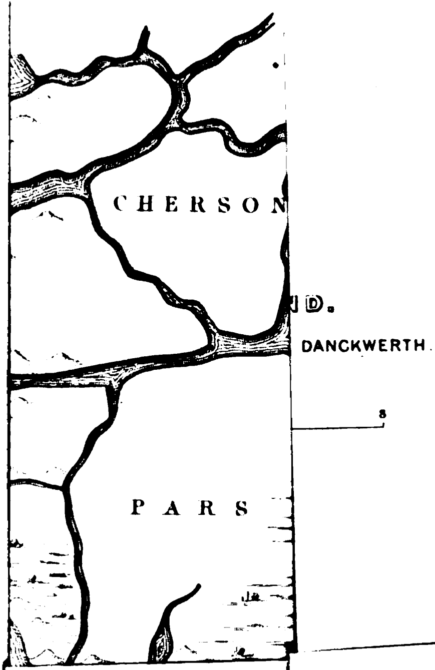
[1] "Through the exertions of Colonel Vermuyden and his successors, a district has been reclaimed from the sea in England larger than the Province of Holland itself." "Sir W. Dugdale, in his 'History of Embanking and Draining,' reckons that the amount recovered in England is equivalent to the whole United Provinces."—(*Vide* "The Engineering of Holland," by Hyde Clarke, in 'Weale's Quarterly Papers,' Part iv., vol. iv., p. 5.)

PLATE 15, VOL. XXI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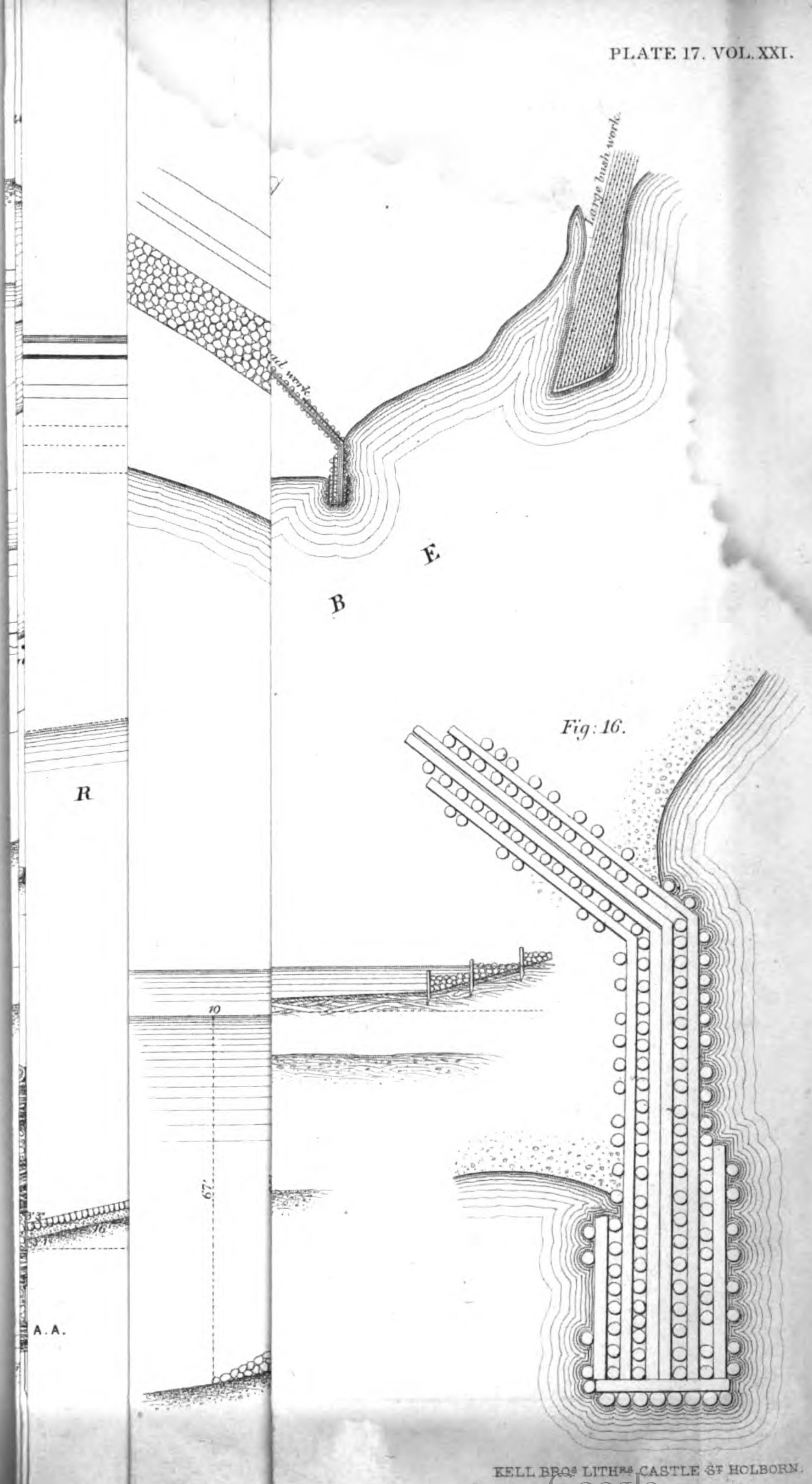
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Fig: 16.

KELL BROS LITHRS CASTLE ST HOLBORN.

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Mr. Hyde Clarke,[1] that there are at least 600,000 acres of land, worth from £20 to £60 per acre, which might yet be reclaimed in England and Ireland, and if to this calculation be added similar districts in the two other countries alluded to, the importance and magnitude of these resources can scarcely be overrated. It must not be forgotten, also, that at the present day these reclamations can be carried out, and the results accomplished, at a far less expenditure than formerly; because, as in all great engineering works, the experience has been gained and paid for. Vast districts, which otherwise would have remained submerged, can now, through the aid of steam power (so economically applied for these purposes), be recovered with greater facility than in the earlier days of reclamations from the sea. It is a remarkable fact, however, that notwithstanding the immense success and manifold advantages which have been derived from these important works, such projects should still be regarded by influential people with suspicion and distrust, although they unquestionably present, under judicious care, the means for the soundest and most profitable application of capital. The Author trusts that ere long such impressions will be removed, and that capital will flow once more in this channel, and be applied to the development of these great resources.

The communication is accompanied by a series of diagrams from which Plates 15, 16, and 17 have been compiled.

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[1] *Vide* "The Engineering of Holland," by Hyde Clarke, in 'Weale's Quarterly Papers,' Part iv., vol. iv., p. 12.

[APPENDIX,

APPENDIX, No. 1.

KING WALDEMAR'S rent roll, or register of taxation, under the head of 'Vesterland,' states the islands along the coast (Plate 16) to be as follows:—Fanö, Manö, Römö, Listland, Sylt, Fohr, Amrom, Oland, Gjestanaka, Hoola Minor, Hoola Major, Hossa, Holm, and Heligoland. It is remarked of them all, that they are inhabited, so that the smaller islands and 'Halligs,' which at that time were innumerable, were not included as being of any importance on the West Coast.

To the map of North Friesland (Plate 15), which the Author has extracted from Danckwerth (a kind of Danish Doomsday Book), he has added the word 'traditional,' because he believes it to represent the country at a much earlier date than is usually supposed. But although traditional, no doubt reliance may be placed upon its general accuracy, for traditional records form an important feature in Scandinavian history, and in many instances are as truthful, as if the events they chronicle had been inscribed on the page of history, at the time of their occurrence. In the Icelandic Saga of the 'Burnt Njal,' (Mr. Dasent's) some singularly interesting accounts are given of occurrences which, although only traditionally recorded, are beyond all doubt.

With the east wind there occurs the highest water. In the Fiord at Flensborg, the water has risen 10 feet over ordinary level; while the same winds blow it away on the western side. In March, 1856, the navigation of the Elbe, for some miles down the river, experienced a complete stoppage, for want of a sufficiency of water, in consequence of the easterly winds which had continued for some days; and even the city canals could not be traversed by lighters.

After a great flood, the people in Nordstrand (Plate 16, General Plan) constructed some dykes themselves. The Dyke Inspector, in reporting upon these works, stated their deficiencies to be, the steep front slope, the wooden bulwarks before the dykes, the insufficient height of the crest, and the total neglect of the 'watt,' or area in front of the dyke towards the sea.

APPENDIX, No. 2.

The Great Danneverke, which has been alluded to, is an earthen wall, or rampart, and originally extended from the town of Schleswig to Hollingstedt, about 12 English miles. It was constructed for the purpose of protecting South Jutland, or Schleswig, from southern invasion, which in earlier times was continually taking place. It is most admirably situated as a line of defence, the position being chosen entirely with this object. In earlier times it was protected, and even in later days also, by extensive and impassable morasses. On the south-western side, from Hollingstedt, the land was impassable to an invading army on account of the swamps. It was first commenced in 808, when the portion called Kuhgraben was built by the Danish king, Godfried; and although other kings at later periods—among the rest King Canute—assisted in it, the great credit of the work is due to the celebrated Queen Tyra, who almost rebuilt it in 937. She called together all the inhabitants of the southern country who could lift a spade, and watched over the progress of the work herself from day to day. It had different heights, varying from 30 to 50 feet, with a corresponding proportional breadth; also a ditch, in some parts on the southern side 60 feet broad and 50 feet deep, besides forts at stated distances. It was principally constructed of earth, but in places partly of stone and timber, and was covered with grass, like the dykes. It has proved of immense service to the Danish kingdom. The great Queen Tyra executed it with such extraordinary vigour and good will, that the workmen gave her a more lasting memorial than is ever accorded to engineers of the present day, having placed over her tomb the Runic inscription, "Honoured shall she be in Her grave as the Guardian Angel of Denmark."

The Danneverke has been greatly strengthened in the last year or two, and now presents the most formidable defence against an attacking enemy. A few heavy guns, well served, would render it almost impregnable.

APPENDIX, No. 3.

ACCOUNT OF THE GREATEST STORM FLOODS ON THE COAST OF DENMARK, ETC.

In the year 340 before the Christian era, a great flood occurred in the Cimbrian Peninsula, extending not only over Denmark, but also over Holland. It is termed the Cimbrian Flood.

A.D.

516 Great storm flood, by which the whole of Friesland was covered with water, and six thousand men were drowned.

793 On the 7th November, the North Sea flooded the whole of Friesland, and vast numbers of men and cattle were lost.

806 In December there occurred a storm flood, which overflowed Friesland, and did much damage.

860 The North Sea rose to a great height, and broke through the dykes. The Rhine also, in the Stifts Belan and Utrecht, overflowed.

1015 A flood devastated the land.

1020 Storm and high water on the Elbe and Weser, when the latter river changed its course.

1075 and 1094 The sea broke over North Friesland, from which the dykes did not recover for many years.

1102 Storm laid waste part of Heligoland.

1114 Great storm. Hever rose to an extraordinary height, broke through the dykes and embankments, and swept away the chapel at Gardsand.

1135 High flood. Water broke in everywhere, and much damaged not only Flanders, but also the lands on the Elbe.

1158 A violent tempest occurred, that tore up large trees by the roots, and blew down churches and houses. Innumerable men and cattle drowned.

1164 February 16. Dreadful hurricane, thunder, and lightning, which set fire to and blew down houses. The flood inundated Friesland and all the marsh lands on the Weser and Elbe. Many thousand men and innumerable cattle were drowned.

1170 Flood. The Netherlands covered by the sea, causing considerable damage. Shell-fish taken at the town walls of Utrecht.

1175 and 1176 Floods which covered vast portions of Holland.

1187 High flood. Timbers from houses and men carried away to distant parts of the country.

1195 Oct. 10th. Tempest which destroyed whole forests.

1204 Dreadful tempest. All the marsh lands were inundated, and innumerable men and cattle were drowned.

1210 A large forest, called Apenhold, destroyed by a storm flood (Danckwerth, p. 70).

1216 A tremendous storm flood broke into all the marsh lands, and buried in the Eiderstedt and Ditmarsh upwards of ten thousand men. Heligoland lost so much by this flood that out of nine parishes it had in 1030, but two remained. Nucksand also, a considerable wood on the site of the present beach, between high and low water mark, at Römö, was laid waste and destroyed by this flood.

1219 Nov. 27. Great flood, by which the whole of North Friesland was overflowed, and about forty thousand men were drowned. The island of Nordstrand greatly destroyed, and several churches sunk in the waves.

1220 Flood, resulting in the loss of several thousand men.

1230 and 1237 Flood producing great mortality, scarcely one man or woman in every ten of the population left alive.
1238 High flood, when a large parish—Bollertsand, at present a sandbank near Römö—with its villages, was overwhelmed by the sea.
1240 Eclipse of the sun. The largest and best part of North Friesland and of Heligoland drowned or washed away (Gerhardt. vol. i., p. 235).
1248 Dec. 28th. High flood on both banks of the Elbe. A parish on the west side of Römö with a wood (Holzing) destroyed by this flood (Kuss, p. 14).
1266 Flood, covering a large part of Friesland.
1277 Tremendous flood in the North Sea, by which the Dollart and forty-three parishes were destroyed, and eighty thousand men were drowned in Friesland.
1288 Flood over West Friesland.
1300 Tremendous flood, rising several ells (an ell is equal to 2 feet English) above the dykes. Seven parishes in Idomsharde and eight other parishes in Nordstrand were destroyed. Also Lyst church and Wendingstadt town, and a great part of Pelworm, with many churches.
1320 Dec. 6th. Flood, particularly at Lubeck, the Trave rising several ells above its ordinary level. Holstein was also inundated. Scarcely fourteen days after another flood almost as high occurred.
1334 Tempest which flooded Holland and Friesland.
1338 Flood over Ditmarsh and Eiderstedt. All the marsh lands inundated, the water standing for some time on the land.
1342 The whole of the Eiderstedt and Ditmarsh flooded, and the lives of a large number of men and cattle destroyed.
1344 Flood, when many people perished.
1354 Great flood, called Mandrankel (men drowning). An incredible number of lives lost in the marsh lands. The dykes were damaged, so that years elapsed ere the country could recover from the effects.
1362 During the night of the 8th September, a tremendous storm flood occurred, called Great Mandrankel, when nearly thirty parishes, with their churches and vast numbers of people, were destroyed, and great portions of the islands of Sylt and Fohr were submerged.
1363 Fearful tempest; blew down steeples and buildings.
1380 May 1st. Flood damaged vast extent of country.
1400 Nov. 19th. Tremendous inundation.
1412 Nov. 18th. Great flood, three thousand six hundred persons drowned.
1413 The water broke through the dykes and overflowed Cremper Marsh.
1416 The Island of Mandoe lost a great deal of land by flood. It was formerly 2 miles (Danish) long by 1 mile broad, and had three churches.
1421 Nov. 19th or Dec. 1st. Great flood.
1434 and 1435 Tremendous flood.
1436 Fearful tempest. Large trees blown down, the water rose to an incredible height, and broke through the dykes, causing considerable damage, especially in Ditmarsh, Pelworm, and Nordstrand, where men and cattle perished in great numbers.
1444 Tempest. Meldorf steeple blown down.
1470 Jan. 6th. Flood 1 ell higher than in 1412; broke in at Offenbull in Eiderstedt.
1471 At Nordstrand, Ditmarsh, and other places, the flood broke through the dykes with dreadful violence, and damaged the north part of Ditmarsh and Eiderstedt.
1474-80 Inundations in the marshes. The Eiderstedt overflowed.
1483 Oct. 16th. The fifth Galler flood; vast damage in the Eiderstedt and Nordstrand, as well as in Pelworm parish.
1491 Sept. 14th. Inundation; much corn carried away and cattle drowned.
1501 The sixth Galler flood.
1504 Hertzhorm parish, including the church, destroyed in a storm.
1508 Nov. 11th. Great flood: also in many places in Holland, doing vast damage.
1511 Sept. 1st. High flood; several places under water, and much corn drifted away.

1514 High flood, laying large districts in the Eiderstedt under water.

1515 Flood; also over the coast of Holland.

1521 Feb. 26th. Very high water, that did much damage in Hamburg.

1521 March 15. Water broke through the dykes in Ditmarsh, and damaged buildings.

1524 Flood; houses and gardens washed away.

1530 Nov. 5th. High flood in Holland, and destruction of men and cattle in North Friesland, where fourteen hundred men were drowned.

1532 During the night between 1st and 2nd November, when there was a total eclipse of the moon, a tremendous tempest occurred, with a south-west wind. The water rose 6 feet above the dykes, and covered the marsh lands with 12 feet of water. Several thousand people were drowned, and all their effects carried away.

1533 Flood filled all the marshes and did vast damage to Nordstrand.

1539-61 High floods over Eiderstedt, Ditmarsh, and Nordstrand, &c.

1570 On 1st Nov., a fearful storm flood over all the coasts from Flanders to Denmark. Four hundred thousand men said to have perished, including twenty thousand in North Friesland. In Eiderstedt the water stood 10 feet over the marshes, and did great damage to the islands.

1571 1st Nov. Flood over all the marshes.

1572 21st Aug. Flood over Eiderstedt and the islands, doing much damage. This was called the Corn Flood.

1574-84 Floods over the whole of North Friesland and in the Elbe.

1591 Great flood occurred.

1593 On Christmas Eve, a dreadful tempest arose, whereby Hadstedt, Bredstedt, and many other places had the dykes damaged and destroyed, from which they did not recover for some years.

1594 On 22nd Dec., flood in North Friesland.

1597 Sept. 25th. After three days' tempest, another high flood arose, doing great injury to the country. Men, cattle, and corn perished.

1601 High flood over Holland, with a north-east wind.

1602 Feb. 14th. Flood, inundating the lands and filling the rivers Fleth and Tetenbull.

1610 Tremendous flood, similar to that of 1570, covering vast districts.

1612 High flood; Nordstrand in great jeopardy, many people drowned, and great damage at Ditmarsh and other places. This flood was also very high in Hamburg, doing immense injury, and filling even the churches.

1615 On 1st. Dec., Flood over North Friesland; number of men drowned. In Sudermarsh, all the lands under water, and great damage done.

1625 On 20th Jan. a tremendous storm from the south-west, and on 26th February another high storm flood. Pelworm, Eiderstedt, and other marshes overflowed. The water stood 3½ feet high in St. Katherine church, Hamburg.

1627 Strong south-west storm, which in Nordstrand caused the flood to fill Pelworm Old Koog, and others. This storm continued the whole succeeding month, and in 1628, on the 27th and 28th Jan., a fearful flood, with rain and a south-west wind, arose, filling Pelworm Koogs, which had already been repaired, so as to stand ordinary floods. Cattle and horses drowned and swept away.

1629 and 30 In January and August, Pelworm, the Eiderstedt, and other parts overflowed, by a severe south-west storm, the water reaching Tondern and Ribe. The works for the enclosure begun at Tetenbull and Oldensworth on May 15th, 1599, were greatly damaged by this storm, and the sluices were carried away.

1634 The Great Nordstrand flood, and one of the most destructive. The wind from the south-west (spring tides); but at midnight the wind veered round to the north-west. All the districts were flooded, and a great part of Nordstrand was destroyed.

1639 Aug. 21st. Pelworm exposed to great peril, from very high water and tremendous tempest.

1643 In June a dreadful storm arose, together with high flood, exceeding that of 1634 in height; and again

1648, at Shrovetide, between 14th and 15th February, a more dreadful hurricane arose, combined with an earthquake. Not only were all the marsh lands seriously threatened, but a number of houses and buildings were affected by undulations. Huge forest trees with their roots were torn out of the earth, and many steeples carried off churches.

1651-53 Very high storm floods.

1655 On 4th August, a storm with south-west wind. Dykes broken.

1659-61 Great floods, bursting Bredstedt dykes.

1662-64 Several great floods, bursting the dykes.

1665-66 Storm flood extending over England, Scotland, Holland, and Friesland.

1682 Inundation over the whole Continent.

1717 A fearful and most disastrous inundation over all the marsh districts and islands, doing enormous damage. In Gluckstadt the water stood 12 feet high in the houses.

1756 A disastrous flood on the west coast; Pelworm injured.

1791-94 Destructive floods, with south-west and north-west winds.

1821 Dec. 1st. Continued westerly gales had prevailed for eight weeks, with high floods, when on the 21st Nov. a storm commenced, lasting till 2nd Dec., with earthquakes like gusts of wind, and terrific torrents of rain and hail.

1823 On 11th March, hurricane from the north-west.[1] On Nov. 30th, a storm commenced, which increased as the spring tide approached, and raged without cessation, and without any ebb of tide, day and night for five days. During the last twelve hours the tempest was frightful. The water was 10¼ feet over ordinary flood at Gluckstadt; but it fell suddenly 2 and 3 feet at different places. Altogether the dykes stood this storm remarkably well, but some disasters occurred.

1824 In November and December a storm flood occurred, continuing almost without interruption for more than two months, spreading dismay through the seas of Europe. Considerable damage was done; but although the waves went over several of the dykes, and even old grass-grown dykes that had not suffered damage for forty years received serious injury, still not a single breach occurred during this attack. All the banks erected according to the most approved construction suffered scarcely any injury, after this incessant storm had raged without interruption day and night for sixty-five days, till January, 1825. Still greater apprehensions were occasioned by an inundation of fresh water, which, owing to the large amount of rain that had fallen during three months, accumulated against the inside of the dykes, without its being possible to get rid of it by means of the sluices; the high level of the sea keeping the sluice gates shut.

1825 Terrific storm floods from the south-west, wind suddenly veering to the north-west. The water in the wells rose 5 or 6 feet, and in some places sprang several feet high, out of holes in the marshes. The dashing of the waves was so violent, that the billows receded to the lowest part of the slope, and again rose 2 feet above the top of the dyke. A watering trough of stone, at Hoge, above 1,000 lbs. in weight, was flung a distance of 50 paces.

APPENDIX, No. 4.

In the preparation of the foregoing Paper, the Author is greatly indebted for valuable information obtained through the kindness of the following gentlemen:—

His Excellency Mr. Wolfhagen (Minister for the Duchy of Schleswig).
His Excellency Mr. Hall (Minister for the Duchy of Holstein).
Etatsraad Trapp (Private Secretary to H. M. the King of Denmark).

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[1] In the winter of 1822, two hundred and fifty ships were lost, and about two thousand five hundred men perished.

Professor Forchhammer.
Cancelliraad Juel.
Capt. R. Carstensen, Dyke Inspector.
Cancelliraad Griebel.
Fyr Ingenieur Grove.

He has also consulted the following authorities, and is likewise indebted to Mr. Gundersen :—

"Danckwerth," Landes Beschreibung.
"Saxo Grammaticus."
"Heimreich Nordfriesische Chronisk."
"Kuss, Annals of remarkable occurrences in Nature, Schleswig and Holstein."
"Bergsoes, Danske Stat."
"Baggesen, Danske Stat."
"Forchhammer (Professor and Etatsraad) Om den forandrede Vandhöide ved Danske Kyster."
"Trapp's Statistisk Geographisk Beskriwelse over Denmark."
"Trapp's Dansk Stats Kalender."
"Tetens, Reisen in die Marschlander om der Nordsee."
"Rafn, Annals of Northern Antiquities."
"Nordisk, Conversations Lexicon."
"Schröder, Topographie von Slesvig."
"C. Juel and Knudsen, Slesvigs Provindcials Efterretninger."
"Worsaae, Primeval Antiquities of Denmark."
"C. Bruun, Slesvigske Marsch Oer."
"Lövenskjold, Storm Floods in 1825."
"Fogh," and others.

No. 1,055.—"On Reclaiming Land from Seas and Estuaries."[1]

By JAMES OLDHAM, M. Inst. C.E.

THE practical operation to which the Author intends more especially to draw attention, and in which he was professionally engaged, is that of the reclamation of a portion of Sunk Island, on the River Humber. But before describing the details of the works, he will make some general observations on that river and its tributaries; and on the large amount of matter held in suspension, as well as the degradation going on, not only to the foreshores of the Humber, but also along the whole of the Holderness coast, from Bridlington to the Spurn. The Humber, from the confluence of the rivers Trent and Ouse to the sea, is 40 miles in length. For about the first 10 miles from the sea it has an average width of nearly 6 miles, the remaining portion being upwards of 2 miles in average width. The total area is equal to 80,000 acres. (Plate 18, Fig. 1.) With some trifling exceptions, the shores of the Humber consist of alluvial formation, and the neighbouring districts of rich agricultural land, generally speaking, tolerably well drained, having an average fall of tide, below the surface of the land, of about 17 feet. The foreshore, between high and low water marks, varies from ten chains to twenty chains in width, but in some localities, as for instance, between Sunk Island and the Spurn, it is considerably more. In some parts, extensive tracts of 'outstrays' exist beyond the banks, which are only submerged at average spring tides. These level tracts are covered with marine grasses, which are exceedingly valuable for young horses and sheep in the summer season. The 'outstrays' are called 'growths' in the locality, and also in many old legal documents. The surface level of the banks of the Humber is about 16 feet above the ordnance datum. The rise and fall of spring tides is 22 feet, and that of neap tides 10 feet to 12 feet. The rate of the stream during spring tides is from 4 knots to 5 knots per hour, and that of the stream during neap tides from 2½ knots to 3 knots per hour. The channel at low-water spring tides increases in depth, from about 1 fathom at the confluence of the Trent and the Ouse, to 12 fathoms off the Spurn Point. The Humber is free from bars and other obstructions at its entrance, and the navigation is safe and good, even at low-water, for large ships as far as the port of Hull, and above that, for river vessels.

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[1] The discussion on this Paper was taken in conjunction with the preceding and following ones on a similar subject, by Mr. Paton and Mr. Muller, respectively; and was continued over portions of three evenings, but an abstract of the whole is given consecutively.

At Brough, ten miles above Hull, on the Yorkshire coast of the Humber, the lias formation crops out; but dips beneath the bed of the estuary, and crosses into Lincolnshire. At Hessle the chalk is found, not only passing beneath the bed of the Humber, but also forming the Wold Hills of both counties, Yorkshire and Lincolnshire, rising in some parts of the East Riding to the height of 800 feet above the level of the sea. The chalk dips rapidly between Hessle and Hull, a distance of four miles, being above the level of the sea at Hessle, and 110 feet below the level of the sea at Hull. Although the surface of the chalk rises as it recedes from the Humber, yet at Sunk Island it is also 110 feet below the level of the sea.

From observations made by the Author, in directing the boring of Artesian wells on the banks of the Humber, he has found the strata above the chalk consist of clay, silt, peat, sand, and gravel. There is a compact bed of strong gravel from Hull to the sea coast at, or about, 60 feet below the level of high water, in which salt water is generally found. At 80 feet below the surface, nuts and leaves of trees have been discovered.

Considering the nature of the soil and the geological formation of the district (alluvium and diluvium), it is not surprising that the foreshores of the Humber, except where efficiently protected by artificial works, should be easily washed away, and that the water should then become loaded with earthy matter, which is again deposited in the less disturbed situations. In addition to the natural deposits which have taken place along the sides of the Humber, and which have assisted in the formation of islands, masses of floating mud are taken by artificial means on to low and worthless lands, by which their surface is raised, and rendered capable of the highest state of cultivation..

It may not be out of place to describe, briefly, the mode of 'warping,' or raising, the surface of low lands by tidal deposit, as practised on the banks of the Trent, the Ouse, and the Don. There are large tracts which were formerly swamp and peat bog land, and many thousands of acres have been, by this process, converted into rich agricultural districts. The usual mode is, to construct a sluice on the bank of a tidal river, and in connection with it a drain, or channel, for the flow of the tide into and over the land to be warped up. During spring tides, the tidal water is admitted to the full flow of high water; the inner door of the sluice is then let down, so that the water is retained until the river has fallen. The mud held in suspension is thus precipitated, and the water which entered heavily charged with alluvial matter becomes clear. The door of the sluice is then raised and the water allowed quietly to escape, leaving behind its load of rich deposit. The Author has known a district, of low and comparatively worthless land, receive, in the course of two and a half years, an average deposit of 3 feet, and thus to be rendered available for crops of grain, within three years from the commencement of the operation. The 'cloughs,' or sluices, are constructed in the ordinary manner, having self-acting tidal doors, and a sliding door which is raised and lowered by machinery. The surface level of districts raised by tidal deposit, is generally surrounded by other similar low lands, and in order to confine the tidal water within the required limits, a temporary bank is constructed by throwing up the earth in the immediate locality. Land warped up, in the mode described, is at once available for crops of grain, and is found to be of the most valuable description for potatoes and other roots; and districts of little value have been converted into rich estates, at an outlay varying from £5 per acre to £20 per acre. The difference of cost depends upon the nearness, or remoteness of the land to the river, and other circumstances.

The waste of land on the banks of the Humber, and on the sea coast of Holderness, is very considerable. On the banks of the Humber the waste is greater above than below Hull. On the Lincolnshire coast, from South Ferriby westward, the loss is considerable. Within the recollection of the Author, in a length of from 3 miles to 4 miles not less than 200 acres of rich valuable land have disappeared. Close along the cliff, or margin of the land, there is a deep channel and an abrupt foreshore. The ravages in this locality threaten to outflank, in a few years, the sluices and lock constructed under the direction of Sir John Rennie, for the Commissioners of the Ancholme Navigation. Opposite the district named, an island of considerable extent, called Reed's Island, has been formed, on which there is extensive pasturage. The channel between the island and the mainland is from a quarter to a third of a mile in width. This island is still increasing in extent, and the area of the embanked portion may at any time be doubled.

The banks and foreshores, in many districts, are protected against the ravages of the tide and sea by piles, and chalk-stone facings; but where the current sets in deep channels, and undermines the land, such artificial means are of no avail. The only sure mode of protection would be to carry out some well-devised general scheme for extensive districts, which would not only save the existing land, but, in many instances, be the means of adding to it, and in some measure, if not altogether, would cover the cost of such protecting works. These works would also prove a great benefit to the navigable channels of the estuary.

The loss of land on the seaboard of Holderness is very great. By observations made over a considerable period of time along 40 miles of coast, the average waste amounts to about 2¼ yards per annum;—and such is the sure and onward progress of the advancing sea, that within a comparatively short interval of time, whole villages have disappeared. As bearing on this point, the following extract from a Paper presented to the British Association, in 1853, by Dr. Bell, entitled, "Observations on the Character and Measurements of Degradation of the Yorkshire Coast," should be quoted:—

> "There cannot be a doubt that the process of waste and destruction of this remarkably fertile district had been going on long antecedent to any traditional or written history. We find, however, on record a lamentable catalogue of losses on this coast; one field after another has been swept away, and one township after another has disappeared. The village of Auburn has gone; the towns of Hartburn and Hyde, both at one period flourishing places, exist no longer. Owthorne has lately yielded to the same fate; the ancient church of Withernsea has long since disappeared, and its successor, built in 1434, is dilapidated and deserted. Further southward, Kilnsea church exists no longer; the last portion of the fabric (being part of the tower), according to the parish register, fell down the cliff into the sea, February 1, 1831; and the village itself is rapidly following. Camden mentions Pennismerk and Upsal, townships or hamlets in Holderness, neither of which remains at the present day. Nor have the encroachments of the deep been confined to the sea-coast of Holderness, for within the Humber we find that considerable tracts of land have been swept away; as, for instance, Redmare, Frismerk, Tharlesthorpe, Potterfleet, Ravenser, &c. The whole of the Yorkshire coast, south of Flamborough Head, is being continually wasted by the encroachments of the sea; and it is a startling consideration, that in the course of a few years, if the same process continue, other towns and villages, now flourishing and fertile, are doomed to follow. The rate of loss, however, throughout the line is not uniform; the physical features, and the geological composition of the cliffs, the set of the tide, and other minor causes influence the degradation to a greater or less degree."
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> "The line of coast to which my remarks apply extends about forty miles, and is now losing an amount of rich agricultural soil of 2¼ yards annually."

Although it has been ascertained that the average loss on the whole coast of Holderness is 2¼ yards per annum, yet the progress is far from uniform, for in some districts little or no change is perceptible for a length of time; but in other localities 10 yards or 15 yards will disappear in twelve months, or before a check is given nearly double that quantity in the course of a couple of years. Accurate measurements have been made from fixed points, at various parts of the coast, at different periods since 1786, and therefore the rate of waste may at any time be correctly found. Sufficient has been advanced to prove the loss of land both on the sea coast, as well as on the shores of the Humber; and an attempt will now be made to show what becomes of some portion of the débris under tidal influence, and the remarks of the Author, on this point, will be confined, chiefly, to the accretion and formation of Sunk Island and its immediate locality.

By reference to Plate 18, figs. 1 and 2, it will be seen, that

Sunk Island is situated on the north bank of the estuary, and that it has a coast line of about 6½ miles. It contains about 7,000 acres of inclosed land under cultivation, the property of the crown, and separated by a narrow creek or drain. There are tracts of co-existent accretions, which have an area of 3,000 acres more, belonging to other parties, and forming additions to the mainland of Yorkshire—making altogether a total of 10,000 acres of rich alluvial soil, the greater part of which has accumulated during the last seventy or eighty years. At the time of Charles I., the island did not contain more than 9 acres of inclosed land, and lying nearly two miles from the coast of Yorkshire, it could scarcely be seen at high water of spring tides. At that time, and until about the close of the last century, a deep ship channel existed between the island and the Yorkshire coast. This was known as the North Channel, and the remainder of it still exists just within the Spurn, being at the point opposite the end of Trinity Sand; three quarters of a mile wide at low water of spring tides, and 12 feet deep towards the centre.

The most ancient map showing Sunk Island, that the Author has been enabled to discover, is that by Captain Greenvill Collins, Hydrographer to his Majesty Charles II., and is to be found in his work entitled 'Great Britain's Coasting Pilot.' The original island only contained 9 acres in the time of Charles I. The Author is of opinion, that the whole of the deposit forming this island and the neighbouring accumulations, is from the sea face of the coast of Holderness; and his conclusions are based on the following considerations:—The deposit can only take place when the water is in a quiescent state, and the time when this occurs, is at high and at low water. Now, as the accretions cannot be produced at low water, except in some instances and to a small extent, it must follow, that they can only be formed at high water. Taking, therefore, the time of high water as that when the mud held in suspension by the tide is deposited, the question follows, from what direction has the tide last come at the time of high water? The deposit could not have come down the Humber, seeing that the current has been running up for the period of five hours, the time the tide occupies in rising; and, therefore, whatever might be floating in the water at flood tide would be conveyed up the estuary. Hence the matter, forming the accretions in question, must have come in with the tide, and have been deposited at high water. The following quotation, from the 'Geology of the Yorkshire Coast,' by Professor Phillips, supports this view. He says at page 30, speaking of Spurn Point:—"The materials which fall from the Wasting Cliffs between Bridlington and Kilnsea, are sorted by the tide, according to their weight and magnitude; the pebbles are strewed upon the shore, beneath the precipice from which they fell; the sand is driven along and accumulated in little bays and recesses; whilst the lighter particles of clay are transported away to the south, making muddy water, and finally enter the great estuary of the Humber, and enrich the level lands under the denomination of Warp."

The soil at the surface, and to a depth of 5 feet, or 6 feet, is found to be of an exceedingly fine alluvial description. Below this, sand and drift gravel are found, to the depth of about 30 feet, then 8 feet or 10 feet of strong clay; below which there are from 14 feet to 16 feet of silt, or sand and clay of a loose description; then follow 17 feet of loose chalk, clay, and stones; after that 30 feet of gravel and stones, resting upon a bed of clay of 5 feet thick; making a total depth of about 110 feet, before the chalk formation is arrived at. These particulars of the substrata of Sunk Island are taken, chiefly, from the description of a boring made by Messrs. Easton and Amos.

As to the nature, and the constituent properties of the Humber deposits, the Author would draw attention to the analyses by Mr. J. D. Sollitt, of Hull, who in 1853, presented to the British Association a Paper "On the Chemical Constitution of the Humber Deposits." He says—"By far the largest constituent part of the Humber mud is an exceedingly fine sand, the particles of which are so minute as almost to float in water, and being of such a quality as to render the whole perfectly unstable, and liable to be moved about by the slightest motion of the water; many of the particles of this sand, when examined by a powerful microscope, appear to have their corners worn down by the attrition of one particle against another, so as to be reduced to nearly a globular form, and great numbers of those particles are so small, as not to be more in diameter than a fourth part of that of a globule of human blood, or about $\frac{1}{12000}$th part of an inch: hence the sand which forms about 75 per cent. of the Humber deposits is, so far as relates to its particles, almost in the condition of a fluid, easily displaced and driven about by every tide, both when it rises and when it falls. In a gallon of water taken from the Humber, when the water was agitated by the tide, there were from 315 to 320 grains of this above-named fine deposit, and it was so exceedingly fine, as not all to have settled at the end of ten hours from the taking of the water from the river."

Six samples were taken from different parts of the Humber for analysis, and the following is the result of the analysis of one of the six, which was from water taken out of the Humber at Grimsby, nearly opposite Sunk Island:—

"Fine sand	76
Alumina	10
Carbonate of lime	2
Soluble salts	5
Oxide of iron	3
Organic matter	4
	100

"This sample contains no carbonate of magnesia."

The accretions in the Humber generally, and of Sunk Island in particular, are found to rise until the average surface level is coincident with the average surface rise of all tides, and when this elevation of the surface has been attained, the vegetable action commences, and marine plants make their appearance.

The first vegetable life, which presents itself on the soft mud surface, is the well-known marine plant rock samphire, or 'Crithmum maritimum.' This is followed by a variety of wiry rush-like grasses, of the sedge genus, and several descriptions of plants, having strong deep-shooting roots, and flat wide-spreading heads which rest on the surface of the ground. When the surface of the salt water accretion has become covered with vegetable life, and the ground is well consolidated, it is considered in a suitable state to be embanked. Sufficient proof exists, that where embankments of new accretions have been made, before the surface has become covered with vegetation, a long period must elapse before the land can be rendered productive, and that it remains, in a measure, waste and worthless. This, however, is not the case where the accretions are from fresh water deposits, or where but little salt exists in the water.

The mud of the Humber is rich in microscopic insect life, having a great number of species of infusoria, and especially that which is known as the 'diatomaceæ.' It becomes, therefore, a question, whether these and other animal existences, together with the vegetable action going on, are not the powers employed in converting the raw material of the deposits of the Humber into a state capable, when matured, of bearing grain and roots; and that until they have accomplished their work, the salt water accretions must remain comparatively barren, for a considerable length of time.

As the land on the margin of the Humber approaches the state in which it is usually deemed to be of sufficient surface elevation and in such a condition as to be available for agricultural purposes, it is found, that many natural creeks and watercourses exist, and frequently, also, pools or low swampy places. These watercourses are in a great measure due to the existence of the pools, for after each tide overflows the land, the pools, or swamps, hold a considerable portion of water, which running out in the course of the ebb tide, has the effect of scouring out the various creeks. It is remarked, that so long as any of these reservoirs retain the tidal water, the creeks scarcely ever silt up, and should the land be embanked while in that state, the surface is found to be uneven and impaired in value. It is necessary, therefore, that for a year, or two years, before the operation of embanking is commenced, the surface of the ground should be drained by 'gripping,' so as to let off the whole of the standing pools. Immediately this is accomplished, all such depressions rapidly silt up, until one uniform plane is the result; with the exception, it may be, of some of the larger outfalls of the creeks; and even these will in a great measure disappear, when the drains are afterwards formed for subdividing the land, and the soil can then be carted from the excavations of the fence drains, into any of the old creeks which may remain. In some cases, however, the natural creeks become the fence drains and the divisions of the fields, and thus save expense in the cost of subdividing the land.

It is scarcely necessary to say, that prior to setting out the lines of the sea banks, a careful survey of the ground, and correct sections are indispensable. When the levels have been taken, the first point to be settled is the permanent drainage of the land about to be inclosed, so that a draining sluice may be immediately constructed to run off any accumulation of water in case of need. In fixing upon the site of the sluice, two considerations present themselves, first, the natural fall, or inclination of the surface of the land to one point, and secondly, the best site for the outfall, so as to effect a perfect system of drainage. The relative depth, or level of the cill of the sluice will be determined by collateral circumstances; such, for instance, as the rise and fall of the tide, and the condition, nature, and extent of the land to be drained.

In determining the sectional form and area of the bank, the Engineer must be guided by the height which will be necessary to prevent the possibility of an overflow, the situation in relation to the character of the waves rolling on to the works, and the nature of the materials to be used in the construction. Where the outer face is exposed to a heavy rolling sea, the slope or angle must be very gradual and extended, so as to prevent a heavy surge and disturbance of the face of the works; and should the soil used in the construction be of a light and sandy description, it becomes necessary to give an extensive base to the bank, and an easy and gradual inclination. In many situations, considerable allowance must be made for settlement and consolidation, otherwise the bank when completed may prove too low and have a distorted appearance. When the material to be used in the formation of sea banks is of a light loose character, it will be necessary to obtain clay, where it can be found, from the nearest locality, to form a strong puddled wall, to be carried up in the centre of the bank, so as to prevent the possibility of leakage through or under the works. If a slip takes place, in any part of tidal embankments, great care must be observed not to allow any fascines to be used, as there is always a danger and liability of fagots forming conductors for the water.

In order to preserve the outer, or sea face of the bank against the action of the water, it is desirable to face the slope with sods, bearing the marine grasses. These sods should be cut from 4 inches to 6 inches in thickness, and be well beaten into a regular form, in order to preserve a smooth surface. On the top and the land side of the bank, the fresh-water grasses will soon grow after the completion of the works, and, therefore, it is not necessary that those portions of the bank should be covered with turf in the first instance.

In illustration of the foregoing remarks, the Author will describe the works of the last embankment at Sunk Island, on the Humber, for inclosing about 700 acres of new accretion. In 1849 he presented plans and reports to the Commissioners of Her Majesty's Woods and Forests, of the nature and extent of the works to be performed, the foreshore, having been previously reported by him, to be in a fit state to be inclosed. The works were commenced in the spring of 1850 under his direction: their execution was contracted for, by Mr. G. C. Pauling. By the general plan of Sunk Island (Plate 18, fig. 2), it will be seen, that the portion of land under consideration is situated at the eastern extremity of the island, and that it has a narrow creek, called the Patrington Channel, on its north side. The line of bank extends from **A** to **B** and from **B** to **C**, and has a total length of 6,067 yards; **A** to **B** being 2,124 yards, and **B** to **C** 3,943 yards. The portion **B** to **C** having to encounter the rough storms of the Humber, and the surface level of the ground in the line of bank being lower than from **A** to **B**, necessitated a much stronger and higher embankment. At **B**, the sluice and outfall of the drainage were constructed, that point proving the most suitable for the purpose, and having the advantage of a short run into the Patrington Channel. The greatest height of the bank from **B** to **C** is 8 feet 10 inches; it is 4 feet wide at the top, and has a total width at its base of 61 feet. The outer or sea face was originally constructed with a slope of 5 to 1, and the inner face, with a slope of 1 to 1½. (Plate 18, fig. 4.) Along the inside of the bank, a drain was excavated, at a distance of 6 feet from the foot of the slope; its average width is 10 feet at the top, and its depth increases from 4 feet at **C**, to 6 feet 6 inches at **B**. The average height of this portion of the bank is 7 feet 6 inches, above the level of the land in the line of the works. The greatest height of the bank from **A** to **B** is 7 feet 6 inches. It is 3 feet wide at the top, and has a total width at its base of 32 feet. The outer face was constructed with a slope of 3 to 1, and the inner, with a slope of 1 to 1. (Plate 18, fig. 3.) Its average height is 6 feet 3 inches. On the inner side of this line of bank a carriage way was left, and a drain was excavated beyond it, of somewhat larger dimensions than the one from **B** to **C**, for the purpose of conducting a portion of the drainage of the old inclosure to the new sluice and outfall.

In constructing the banks, the contractor was required to use the soil excavated in forming the drains, and the remainder was to be taken from the ground lying outside the line of works, but under the restriction that the excavation was not to be made within 6 feet of the outer slope, and that it was not to exceed 4 feet 6 inches in depth. In order to prevent the danger of a slip, and damage to the works, the sides of the excavations nearest to the banks were not to have a less slope than 2 to 1, and the contractor was also to provide channels, for the purpose of discharging the water which might be accumulated in the pits after each tide. Within about three, or four years after the completion of the banks, the pits from which the soil was taken, were silted up to the general level of the land by tidal deposits.

In carrying out the works, gangs of men were set on at several places along the line, so as to raise the bank fully to the height of ordinary spring tides, but the principal natural creeks were left open for the escape of tidal water. The creeks were afterwards simultaneously filled up, and the whole embankment was brought to one level and to the full height required. The works were commenced in April; by the commencement of July, the tides were excluded from the land, and in the December following the whole was completed.

The contract price was 4*s.* 6*d.* per lineal yard for the portion from **A** to **B**, and 10*s.* 6*d.* per lineal yard from **B** to **C**; the former amounting to about 4¼*d.* per cubic yard, and the latter to 5¼*d.* per cubic yard on the average. The sluice was not executed under contract; the cost was £380. A stipulation was made with the contractor, that he should keep in proper order and condition, and bear the whole risk and responsibility of the works, for a period of twelve months after the date of their completion; and he was paid an extra sum for the drain from **A** to **B**.

The nature of the soil of Sunk Island is such, that it so consolidates and unites, as to be perfectly compact and impervious to the pressure of water, therefore no difficulty was experienced in that respect, and the entire lines of banks, formed by the material found in situ, proved from the first, perfectly watertight.

The total settlement from **B** to **C** amounted to 15 inches in the highest part of the bank, and it was partly due to the consolidation of the soil forming the bank, and partly to the subsidence of the ground on which the bank rested. There was very little settlement on the line from **A** to **B**, as the ground on that part of the inclosure proved much firmer.

The construction of the self-acting draining sluice is shown in Plate 18, figs. 5, 6, 7, 8. The tidal doors close by the pressure of the flood tide, and open when the water of the Humber has fallen below the surface level of the water in the drain. The foundation of the sluice consists of bearing piles, each about 12 feet, or 15 feet long, having cills bolted to the heads, on which a platform of red wood planks, 3 inches in thickness, is fitted and spiked. There are also four rows of sheeting piles 6 feet long and 11 inches by 3 inches in section. The superstructure consists of brickwork and stone copings. The hollow quoins of the gates, the framing of the gates, and the top cills and pointings, are of English oak; the bottom cills and pointings are of elm timber.

The fresh-water door is raised and lowered by machinery (Plate 18, figs. 9 and 10), and is used for the purpose of holding up fresh water in the drains, and for flushing and scouring the sluice and outfall, which is liable to be silted, in the summer, or when but little fresh water is running out. In very dry seasons, the sluice is used for taking in a quantity of tidal water, to fill or charge the fence ditches, and the cattle are thus prevented from straying; for the fields are generally only divided by ditches, and as the subsoil is of a sandy and porous nature, the water in them rapidly disappears.

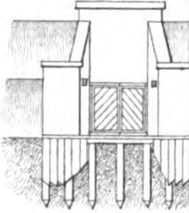
Soon after the exclusion of the tidal water from the surface of newly-embanked land, the marine grasses and vegetation begin to die and decay, and in the course of a year, or two years, fresh-water grasses appear. After the lapse of about three years, a tolerably good surface of pasture is naturally formed, and it is capable of sustaining a considerable number of cattle. But that which is most surprising, is the spontaneous appearance, and the growth, on the inclosures of Sunk Island, of an entire covering of white clover, which presents itself within three years, or four years of the date of the exclusion of salt water.

Hitherto, the Author has only noticed the availability of embanked accretions, as grazing or pasture land, but a few remarks will not prove uninteresting as to their value for tillage. After the completion of the embankment, and the subdivision of the land, a selection is made as to what portion shall remain as pasture, and what shall be worked by tillage. Some trifling labour devolves on the farmer, in levelling irregular places on the surface; he then ploughs and prepares for a crop, and

CLOUC

RINGTON CHANNEL

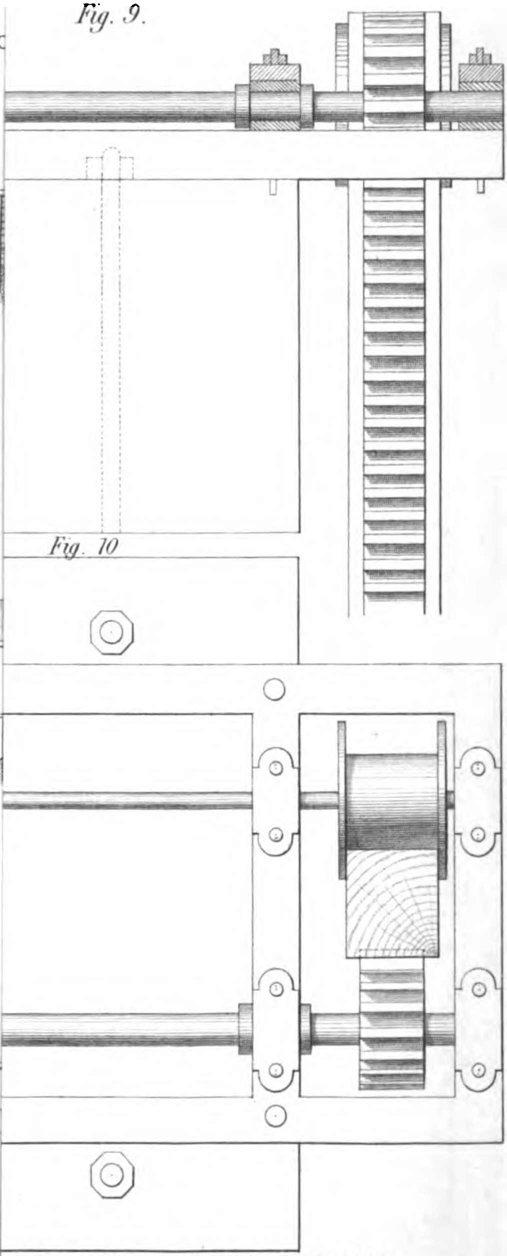
Fig. 6.



DOWN STREAM ELE

Fig. 9.

Fig. 10



EVATION AND PLAN OF LIFTING GEAR

KELL, BROS LITHRS CASTLE ST HOLB

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generally the first on the land is rape. This is sown about the third year or fourth year after the inclosure, and the produce is usually of extraordinary quantity and vigour. The following season oats, or beans may be sown, and then wheat, and perhaps, of all the districts of England, the largest and best crops may be found on Sunk Island, for the tenants admit that the land produces upwards of six imperial quarters of wheat per acre. Flax also is produced of a fine and valuable quality, and in large quantities. The producing power of this description of land is not limited to the growth of cereals, or fibrous products, but the finest roots, such as potatoes, turnips, mangold wurzel, &c., are successfully cultivated. The climate is generally mild through the winter, with trifling exceptions, but it is hot in the summer. The rain-fall amounts to about 18 inches, on an average, per annum. The harvest, is frequently from one week to two weeks earlier than in the surrounding neighbourhood.

Patrington Channel is a narrow muddy creek, along which river vessels of 50 tons burthen may pass at spring tides ; but for want of back water for flushing, or scouring, it is difficult to maintain a navigation. It is therefore to be feared that it will soon cease to be navigable up to Patrington Haven. This channel defines the limits of Sunk Island to the eastward, and as the accretion is rapidly forming in that quarter, a few years will prepare a large increase to the available surface of the island, which, whenever it reaches its limits in that direction, will add about 3,000 acres to the present tenantable holdings, and make a total in Sunk Island alone, of about 10,000 acres.

In 1854, the Author made surveys of the district between Sunk Island and the Spurn, with a view of embanking about 10,000 acres; but certain circumstances arising, further proceedings were, for the time, abandoned. The project, however, is not lost sight of, and it is probable that at a not very distant period, a rich tract of land will be obtained, and by such a result a more permanent security be given to the Spurn itself, which is far from being in a safe, or satisfactory state, owing to the onward ravages of the sea, as already described, along the Holderness coast. There is no doubt, but that the loss of the promontory, would occasion an incalculable injury to the safe navigation of the Humber, and one which perhaps could never again be remedied.

This Paper is illustrated by a series of diagrams, from which Plate 18 (figs. 1 to 10) has been compiled.

No. 1,066.—"On Reclaiming Land from Seas and Estuaries."[1]

By JOHN HENRY MULLER (of the Hague).

THE class of reclamation works, to which the Author would more especially refer, is the inclosure by embankment, and the drainage by natural means, of an area, or areas, of salt-marsh, samphire ground, slake, mud, or sand lying more, or less above the level of low water.

Projects of this character have too often been set aside, upon insufficient grounds, and from want of proper consideration. In some instances, the state of the soil has been incorrectly pronounced unsuitable for the purpose; in others, undue importance has been attached to the probable contingencies where water has to be dealt with, or the circumstance, that the benefits to be derived were chiefly prospective, has unduly influenced the decision of those interested. It has also been stated, that at best such projects could only be considered as hazardous speculations; and sometimes opposition has been offered on the erroneous supposition that the reclamation of land has the effect of producing fever and ague. To these objections sufficient answers can be given. It may be replied, that the value of the ground before being reclaimed is no measure of the merit of the proposal for its inclosure, as that can only be decided by comparing the cost of the necessary works, with the improved value which would be given to the land by their execution. When the reclamation is proposed in front of a previous inclosure, it frequently occurs, that the existing banks are so damaged by every storm, that if the reclaimed land only produced sufficient to maintain the new banks, the expense of repairing the old ones would be saved. No doubt there are projects of this nature of a questionable character, as so much must depend upon the position of the proposed works in reference to the centres of population. As for instance, supposing that it was proposed to inclose a narrow slip of foreshore, by a long bank, in a locality situated far from habited places, however good the soil might be, such a work in all probability would be a failure. While, on the contrary, the reclamation of a large area of bare sand, in the neighbourhood of a town, by means of a short bank, might prove a successful undertaking. It may safely be stated that the inclosure of the foreshore has the effect of removing the malaria which is the cause of fever and ague. This disease, it must be remembered, is always prevalent in districts which border on low marshy foreshores. In Holland, where nearly the whole of the land has been reclaimed from the sea, and in other similarly situated countries, there is no well-authenticated instance, where an increase in fever and ague, has been the consequence of a reclamation. As regards the commercial question, the Author admits that these enterprises are not unattended with difficulties, but he contends, that they are not greater than can be surmounted by ordinary engineering ability. And on the whole, it may be safely asserted, that if projects of this class are well selected and prudently carried out, they will prove alike remunerative to their undertakers and beneficial to the community.

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[1] The discussion upon this Paper, in conjunction with the two preceding ones on a similar subject, by Mr. Paton and Mr. Oldham, was continued over portions of three evenings, but an abstract of the whole is given consecutively.

In designing the works for effecting a reclamation, the principal object to be kept in view, is to inclose the largest area, with a bank of the least length, and the smallest average cross section. These points are regulated by the direction of the outer portion of the embankment, or sea bank. It is sometimes recommended that it should be, as nearly as possible, parallel with the current, and at an acute angle to the prevailing winds. But experience seems to show, that where creeks do not interfere, a different system is preferable. When the embankment is placed at an acute angle to the prevailing winds, the force of the wave acts on a greater length of bank, without much diminishing its intensity. A current which runs parallel to a bank, also occasions a chafing similar to that which is produced by the action of a stream on the sides of a river. The Author believes, that it is best to construct one side of the embankments boldly exposed to the full force of the gales, so that the sea bank will shelter, or protect the other two sides. By this arrangement, a less extent of bank requires supervision during gales, and in executing the work, if the sea bank is first made, the other two sides can be finished in comparative security. A direction, at right angles to that of the current, also possessed advantages, on account of the small extent of bank which is acted upon by the current, and the eddy which is produced occasions an accumulation which forms a protection, throughout a considerable length of the bank. Indeed, the direction of the original currents are generally so much changed, by the altered outline of the foreshore, that in most cases it is only necessary to take the current into consideration with regard to the difficulty of constructing the bank, but not with regard to its maintenance.

A diversity of opinion exists, as to the extent of land that should be reclaimed at any one time. The Author considers, that in most cases, large areas are the least expensive in the end; or if a small area is selected at first, some portion of the original sea banks will be useless when an increase becomes desirable. Between the old sea bank and the edge of low water, the soil may be divided into four distinct classes (Plate 19, fig. 1):—the salt marsh, of clay, about the level of summer spring tides; then samphire ground, slake, or mud, or rich alluvial matter, to half tide; next, hard sea sand; and lastly, near low-water mark, quicksand. A narrow slip of salt marsh and samphire land is usually recommended to be first inclosed, in the expectation that in a few years, the foreshore outside it will accumulate to such an extent, as to enable it to be reclaimed by banks of smaller section and less cost. But experience has shown, that if the banks cannot be constructed entirely on the salt marsh, it is preferable to go to half-tide level. Banks entirely on the salt marsh are the easiest to construct, and the strongest that can be made. Those on samphire ground and mud are the most difficult. During their construction, slips are of constant occurrence, the use of waggons and horses is impossible, and a large proportion of the material is washed away, as it is deposited, and before the bank is consolidated and raised above high-water mark. In fact, for waste, settling, and contingencies, from 60 per cent. to 100 per cent. of the original quantity must be calculated upon as necessary. If a storm occurs during the progress of the works, the slopes cannot be protected; and indeed, a bank constructed on such a bottom, is always unsafe. When the line of the embankment is laid at the half-tide level, or about the limit of vegetation, and on hard sand, it is possible to make the whole of the reclaimed land fit for cultivation, and this mode of effecting the inclosure need not cost more, and is safer, than when the higher, but softer bottom is adopted as the seat of the bank. When large areas at this level are to be reclaimed, it is sometimes considered necessary, that the species of preparatory banks called 'cradge banks' should be previously carried out from the shore, so that with less area, there may be a less extent of water to contend with, during the construction of the sea bank, but that practice is erroneous, as the difficulty in the construction does not increase with the size of the area to be reclaimed, but depends upon the relative width of the openings left in the banks.

The following instances which have occurred in the course of the Author's professional practice are given in illustration of this branch of the subject:—In reclaiming a piece of land of 1,000 acres, by a bank three-quarters of a mile in length, the seat of which was 6 feet below the level of high water, only one opening 7 chains in width, was left. In another case, in reclaiming 1,700 acres, by a bank four miles in length, the seat of which was 8 feet below high water, three openings, respectively of 5 chains, 7 chains, and 12 chains in width, were left. In neither case was the speed of the outgoing current materially increased, during the progress of the works, nor indeed until the cross section of the openings was diminished. In completing the latter work, the aprons were raised 18 inches, or 2 feet at a time, by wood work, stone, and clay. It was expected that the current would increase in the third opening, when the two others were raised; but this did not occur, as the water within the inclosure did not reach so high a level as that without; in fact, it never attained to high-water mark. When the aprons were above the level of the reclaimed land, the current on leaving became violent. This cannot, however, be avoided in finally closing a bank.

Banks on a lower level than that of the half-tide mark, are not advisable, on account of the shifting nature of the bottom which is ordinarily met with, and the large openings, and low levels, which are required for the outfall sluices.

Having stated the conditions to be observed in the direction and situation of the banks, the next question requiring attention is the cross section. This branch of the subject naturally divides itself into two parts:—first, as to the main body for resisting the dead weight of the water when at rest, and secondly, as to the mode of protecting the slope, to enable it to resist the action of the water when in motion. With regard to the first point, the best cross section is that, in which the centre of gravity comes nearest to the bottom, and to the toe of the bank. For this reason steep slopes with a cess, or bench, about the level of high water, are preferable to flat slopes without a cess, or bench. Sand standing at its natural slope is sufficient to resist still water. Breaches in banks are attributable, either to a small percolation of water underneath the seat, or to the defence or protection of the slope being insufficient. Percolation usually takes place at high spring tides, and from the rapidity with which the bank sinks down, and is overtopped by the stream, but little can be done to prevent a breach from this cause. The insufficiency of the defence, or protection of the slopes of the bank, in many cases arises from mistaken economy. Unless there is a sufficient thickness of protection, the sea breaks through the material underneath, and soon works its way through the body of the bank. It has been urged that the hearting of all banks should either be of clay, or else that they should be constructed with a wall of puddled clay along the centre. Frequently, it is not possible to obtain clay in sufficient quantities for such a purpose, and, setting aside the great expense involved, if the force of the wave is strong enough to break through the outer protection of stone or wood, it is evident that clay will be unable to resist it. When a breach is apprehended on account of the weakness of the protection, it can in most cases be prevented if sufficient material is at hand. At extraordinary high tides, a breach sometimes occurs above the cess, but this rarely happens, and the time during which danger could arise is so short, that the evil may be remedied before the next returning high tide. When the water rises above the top of the bank, the unprotected back slope is liable to be damaged, and thus to lead to a breach. This may be averted by driving stakes into the top of the bank, and placing planks, supported by clay, or other materials, behind them.

With respect to the protection of the slope, there is a difficulty in ascertaining correctly the force of sea-water when violently agitated. Mr. Storm Buysing has stated, in his work on hydraulic engineering, that the shock of the water and of floating objects against a slope, increases in the same ratio as the sine of the angle formed by the slope with the horizon. De la Coudraye and Brémontier contend, in their theory of the motion of waves, that the water only moves vertically, up and down, without any horizontal displacement; but if this were true, the amount of undulation ought to be the same at any depth, which is known not to be the case, the undulating motion being stronger near the surface, and slowly diminishing as the depth increases, until a certain level is attained, when practically the undulation ceases. Opinions differ as to this limit. Some fix it at a level of 6 feet or 7 feet below the surface. Belidor assumes, that the undulation is very trifling at a depth of 16 feet, and that it cannot be observed at a depth of 27 feet; while Colonel Emy maintains that motion may be observed at a depth of 500 feet. These different theories appear to point out, that there is a simultaneous horizontal and vertical displacement of the particles of water in wave motion, but they give no clue to the solution of the question:—What is the minimum amount of strength that ought to be given, under stated circumstances, to certain slopes, in order to resist the maximum amount of power which the sea can exert upon them? At present it is well known that the sea has the power to destroy banks, and to displace stones of considerable weight. The Engineer must, therefore, be guided by experience in dealing with these matters, rather than by speculative opinions.

The materials, employed for the defence of slopes in Holland are of three different kinds, clay and grass flags, wood and stone. When banks are constructed on salt marshes (Plate 19, fig. 2), the body consists of clay taken from the adjoining excavations, the soil of the best quality being reserved for the outside. The body of the bank and the slopes should be well trodden down by horses, and when consolidated, should be sloped afresh, and sown with a mixture of salt marsh—meadow grass, and clover seed, and the whole slope should be protected by a 'crammat.' The crammat, which costs threepence or fourpence per square yard, is composed of a layer of clean barley straw, about two inches thick, evenly laid, and fastened to the clay by straw bands, or strands, sixty to ninety stitches being made per superficial yard. In two, or three years the bank is so consolidated, that the mat does not require renewal. For banks on a lower level than the salt marsh, a protection of clay and grass is insufficient. In such cases, a layer of clay, protected by stone, at a slope of 4 to 1, or 6 to 1 is employed in England, but without a cess or bench. This affords the requisite strength, but it is expensive, and as usually constructed, it needs much repair. When the bank is on samphire ground, it may be expected, that within a comparatively short period a new salt marsh, or foreshore will be formed, which will render the protection unnecessary, and as the stones will then be imbedded in silt, they will not be worth the cost of removal. Under these circumstances, it would be better to form the bank with a cess. The slopes, above and below the cess, need not be flatter than 3 to 1, and while the upper slope would need no protection, it would be sufficient to protect the lower slope with wood, or fascine work. In constructing a bank on this description of ground, wood possesses great advantages over stone, which cannot be laid until the bank is consolidated. A bank having a cess can also be more easily protected during its construction, a 'crammat' covering being sufficient to resist the force of an ordinary summer gale.

The wood, or fascine work protection used in Holland, consists of successive horizontal layers of fagots, 5 inches, or 6 inches in thickness, placed in a direction up and down the slope of the bank, the thick ends overlapping the thin ends of the lower rows. Through these, stakes about 4 feet in length are driven, at intervals of 14 inches, in rows parallel to the direction of the bank. The rows are 16 inches apart, and are fastened down by stakes, which are left 8 inches above the fagots, and are connected together by means of willow binders, or 'wattles,' something like hurdle work. When this is complete, the whole is driven down with a mallet, and every fourth, or fifth stake is provided with a key, to prevent the wattles from lifting. If the proper sort of wood is obtained, this protection will endure from five to seven years, and is quite able to resist the action of the tide. The strength of this kind of protection might be augmented by increasing the number of the stakes and binders, or by filling in with stones, firmly wedged between the rows of stakes. In the application of this class of protection in England, a great improvement has been effected by creosoting the stakes, but the general results have by no means been so satisfactory as those which have been obtained in Holland.

The Author considers, that according to special circumstances, one of the four different sections shown on Plate 19 (figs. 2, 3, 4 and 5) will, in most cases, be found available.

Fig. 2 is the section of a bank on salt marsh. The top of the bank is about 3 feet wide, and 3 feet, or 4 feet above the level of the highest known tide. The inner slope is not less than 1½ to 1; steeper slopes being liable to slip, and not presenting sufficient surface for the growth of the grass intended for their protection. The outer slope of 3 to 1 is covered with a foot of clay, and is protected by a 'crammat;' but when the banks are settled with and covered with meadow grass, the mat is not necessary.

Fig. 3 is the section of a bank above the level of half tide. The top of the bank is 4 feet wide, and 4 feet above the level of the highest known tide. The inner slope is 1½ to 1. The outer top slope is 3 to 1, and extends from the top, to the level of the highest known tide, at which point there is a cess of 20 feet in width, having a fall of 1 ft. 6 in., or 2 feet. The lower slope is 3 to 1. The inner slope and the top are covered with a layer of clay 8 inches in thickness, and the top slope and cess with a layer 12 inches in thickness; and the bottom slope with a layer 18 inches in thickness. The top of the bank and the back slopes are sown with seeds, and the outer top slope and the outer bottom slope are covered with a 'crammat.' The outer bottom slope is further protected by fascine work, in the manner already described.

Fig. 4 shows the additional protection which is requisite as a defence against the sea at a lower level than that of half tide. The section shown in fig. 3 may be adopted for the bank, but the covering layer of clay should be 6 inches more in thickness throughout. The rows of stakes on the outer bottom slope should be placed nearer to each other and be filled with stone. The strength and protection afforded by the fascine work may be further increased by two separate methods:—First, by increasing the number of the rows of stakes and binders; secondly, by reducing the number of the rows of stakes, and by filling up the spaces with stones, put down edgeways, and strongly fastened between the rows with little wedge pieces.

When a bank has to be formed below the level of half tide, the question of the employment of wood, or stone as a protection is one which must be decided by the relative cost of the materials in the locality. But the Author believes, that in most instances, if the compound interest on the excess of the original outlay for stone, as compared with wooden protection, be taken into consideration, the balance in a given term of years will be found to be in favour of the employment of wood, notwithstanding the frequent renewals which it requires. It may further be remarked, that the unavoidable supervision is the same in both cases, that the wooden protection, as requiring less immediate expenditure, is more likely to be preferred by proprietors or shareholders, and that in winter time it affords employment for men, who would otherwise be dependent upon public, or private charity.

Fig. 5 is the section of a bank below the level of half tide, where a stone protection is proposed to be adopted. The top of the bank is 6 feet wide, and it should be at least 6 feet above the level of the highest known tide. The inner slope is 1½ to 1; the outer top slope is 4 to 1, and is covered half way up by a wooden or fascine protection. The cess is 20 feet in width, and has a fall of 2 feet, or 3 feet, and the outer lower slope is 5 to 1, or 6 to 1, according to circumstances, and is covered with a stone defence, such as is commonly constructed by the Dutch, on islands exposed to the ocean. It is formed thus: when the slope is trimmed, a layer of clay, 12 inches to 18 inches in thickness, is spread over it, covered, sometimes, with a 'crammat.' Over this bricks, in one, or two courses, are laid, and then from 6 inches to 12 inches of brick-bats, on which stones from 12 inches to 18 inches in depth are set.

It will be observed, that with a stone defence, the slopes are recommended to be flatter, and the banks to be higher, than where wood protection is employed. In steeper slopes, the rows of stone would rest upon one another, and if a wave removed or disturbed one stone, the removal or displacement of those above it would almost necessarily follow. The bank is made higher on account of the flatness of the slope. If the rule is adopted, that the shock of the wave increases with the sine of the angle made by the slope with the horizon, the momentum remaining the same, the amount of force, or intensity, saved by the flatter slope is expended in the velocity with which the wave runs up the slope. But whatever may be the cause, it is certain that waves ascend much higher on flat slopes than on steep ones; so that, although the shock may not be so great, the protection must be carried up higher.

The stone protection which has been described has in some instances lasted fifty years without renewal; but though very durable, it is costly, and hence should only be adopted where absolute security renders it necessary; as, for instance, for banks near to low-water mark. In exposed situations, an additional width may be given to the cess with great advantage. The wave rushes up the slope until it arrives at the cess, when its direction being altered, it is checked, and if the cess is sufficiently long, its force is almost expended before its direction is again altered by the upper slope. In neutralizing the action of the wave wooden protection has an advantage over the stone. The slope being steeper, more of the power of the wave is expended while rushing up it, and the numerous stakes encountered so subdivide the wave, that it becomes a mere ripple before it reaches the cess. On the other hand, the surface of the stone protection is so smooth, that waves seem invited to ascend. In some cases it has been found advantageous to introduce rows of oak stakes, at intervals above the surface of the stone, to break the force of the waves. The stakes should be about 1 inch or 2 inches apart, and their tops should be 12 inches or 15 inches above the surface of the stones. An oak framework of piles, 12 inches in scantling, connected together by walings, has been used to break the wave in exposed localities, such as those of West Kapelle in Zeeland and Petten in North Holland.

In the construction of sea walls, or banks, the most difficult operations are those connected with the crossing of creeks, before alluded to, especially when the bottom is 10 feet, 20 feet, or more under low-water mark. In England the usual plan is to fill in large quantities of material from the sides, and simultaneously to fill up the middle, by means of hopper barges, with substances hard and heavy enough to resist the current. This method, though in general eventually successful, is costly. In closing a creek or other opening from the sides, as the gap is in the process of contraction, the water tries to gain by increased depth, the sectional area which it has lost by the decrease in width. In Holland, the custom is to raise the bottom uniformly, to the level of low water, by means of cradles, formed of brushwood, and bound together by ropes and osiers. These cradles are usually from 2 feet to 3 feet in thickness, of a length equal to the full width of the gap, and of a proportionate width. Being flexible and capable of stretching to a limited extent, they adapt themselves to all the inequalities of the bottom. In the first instance, a 'wiep table' is constructed in a convenient place. A row of stakes 12 inches or 14 inches apart is driven into the ground. At a distance of 10 inches, a parallel row is then placed in such a manner that the stakes shall be immediately opposite to those of the first row; and the heads of each pair of opposite stakes are connected together by a cross piece about 6 inches from the top. Upon these cross-pieces, the 'wiepen' which compose the framing of the cradle, are put together. 'Wiepen' are usually from 4 inches to 6 inches in diameter, and are made in the following manner:—Loose fagots are laid upon the cross-pieces between the stakes; the separate branches are then pulled out so as to overlap each other like the fibres of a rope, and when uniformly arranged, the 'wiep' is bound together by osier ties at every 4 inches of its length. When a sufficient number of 'wiepen' have been made for the longitudinal and transverse framing, a convenient site is selected upon which to construct the cradle. A flat sand, or silty ground about 3 feet, or 4 feet below high water is the most convenient. The details of the construction of the cradle are minutely shown on Plate 19, fig. 6. It will be observed, that it consists of a lower and an upper framework of 'wiepen.' The lower framework is first put together. The transverse 'wiepen' are laid down in straight lines, about 3 feet apart. Across these the longitudinal 'wiepen' are placed at right angles, but at about 4 feet from each other. At every other crossing the transverse and longitudinal 'wiepen' are alternately tied together, by a long osier, and a strong rope. When the lower framing is completed, the ends of the ropes which have been used are fastened, in such a manner, that they will be ready for further use when the upper framework is laid on. The next operation is to prepare the foundations for the 'props,' or mooring posts to which the cables are made fast while the cradle is being floated to its position and sunk. Particular attention must be paid to the position and security of the props, as the safety of the cradle depends entirely upon them. If placed too near the edge, a small strip is liable to be torn off, and if placed too much in the middle, the edge of the cradle will dip in the water, when, if the current is strong, there will be danger that it may be doubled under and rapidly torn to shreds.[1] If the props come out, the cradle is also liable to injury. It is therefore desirable to have several spare props. In preparing the foundations for the props, two, or four bundles of binders are attached, under the longitudinal 'wiepen;' this is done in six, or eight different places, and to these short 'wiepen' are fixed.

The lower framework and the foundations for the props being completed, bundles of the longest fascines that can be procured are laid between the longitudinal, and across the transverse 'wiepen;' the ends of these should overlap each other 4 inches, or 5 inches. This layer of fascines should be about 6 inches, or 8 inches thick. Another layer of the same thickness is then laid across the last, at right angles. Alternate layers are thus laid until the required thickness is attained. A frame similar to the lower one is constructed on top of the fascines, the longitudinal 'wiepen' being first laid, and then the transverse 'wiepen.' The cradle is now bound together as tightly as possible at all the crossings, with the ends of the ropes which were used for the lower framing. Square spaces are then constructed for holding the stone ballast, by driving stakes through the longitudinal and cross 'wiepen,' and connecting them with wattling. The props are driven into their places and connected by strong ropes, and the lower and top 'wiepen' are tied together, all round the cradle, at convenient distances with ropes, and to these are attached large iron thimbles, which come into use when the cradle is sunk. To secure the cradle in its position, six, or eight anchors are laid out with cables attached to them, which are also made fast to the props. The anchors are so disposed, that the rising tide may lift the cradle, without changing its horizontal position. In Holland, these cradles sometimes contain an acre of surface, and their thickness varies from 2 feet to 6 feet, but the largest which the Author has sunk in England was only 150 feet long and 45 feet wide.

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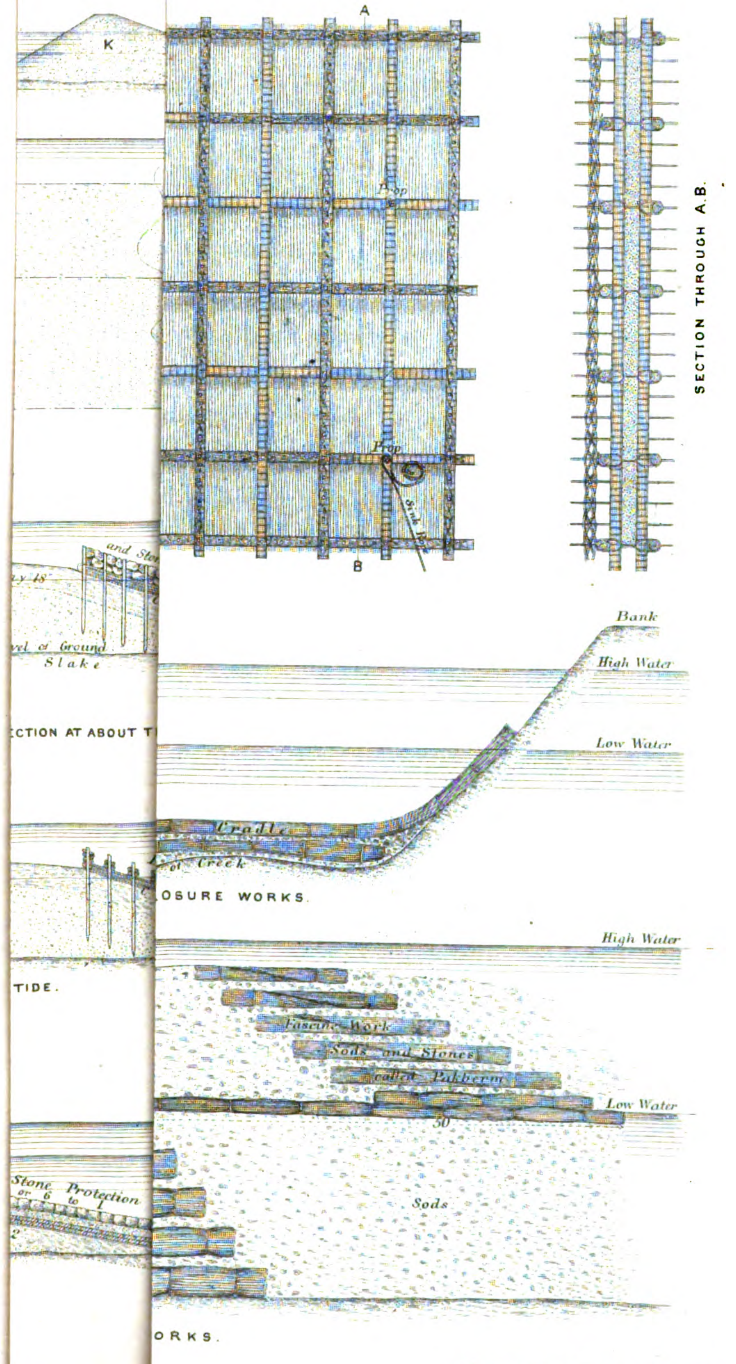
[1] The props in fig. 6 (Plate 19) are only shown for the purpose of illustration, but in constructing a cradle the above considerations should determine their exact position.—J. H. M.

When it is determined to move the cradle, it is accompanied to its destination by a sufficient number of flat-bottomed boats, the draft of which should not exceed 18 inches, or 24 inches when laden. These are partially loaded with sods of salt marsh, of about 8 inches cube, or 9 inches cube, on top of which are placed as many stones as the boat can safely carry. Two men are required for each boat. To prevent accidents, the cradle is kept, as long as possible, out of the strength of the stream. It is floated to its destination with the aid of a relay of anchors and cables, the spare anchors being dropped close to the cradle, before the previously laid cables are entirely slacked out.

If the cradle is to be sunk at low water, it should be in its position an hour, or two hours before that time. When in the centre line of the embankment, the cables which hold it are made fast with slip knots round the props. The boats then come close to it, those on the in-shore side of the cradle hanging on by their own anchors and cables, and those on the outer side by the cradle itself, but at the same time, connecting their masts by ropes with the masts of the boats on the inner side, so that the strain on the cradle may be reduced as much as possible. In each boat there are two ropes, called 'sinking lines.' These are passed through the thimbles which were previously attached to the sides of the cradle, and are temporarily secured inside the boats in such a manner that the cradle, when laden, will be supported by them. The stone from the boats is then unloaded; the receptacles in the central portion of the cradle are first filled, and then those along the sides, until the whole cradle is a few inches under water and hangs entirely by the sinking lines. At a given signal the cradle is gradually and uniformly lowered to the bottom. The remaining portion of the boats' cargoes is discharged, and the sink lines are pulled up, but the cables are left round the props until the following day, when the power of the rising tide is employed in weighing the anchors, and in pulling adrift the slip knots. In the succeeding tides the cradle is further weighted, by clay, brickbats, and stones. It has been calculated that a cradle of 1 foot 8 inches in thickness should be loaded in the following proportion:—8 inches in thickness of clay, 6 inches or 8 inches of stone of a specific gravity of 2·6, and about 6 inches of brickbats. Filling up a gap by this method possesses the great advantage that there is comparatively no loss, or displacement of the material. There is no chance of any scouring taking place under the cradle, and the hollows between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the lumps of clay and stone being soon filled up with sand by the tide, the bottom of the creek, or gap is, in a few hours, permanently raised several feet.

The sides of the opening are next protected with similar cradles, the lower end of each resting on that first laid. Subsequently, other cradles are sunk over these, until the work reaches low-water mark, when the width of the embankment is gradually increased, by throwing in sods on the outer side, protected by fascine work, weighted with stone. The same process is then pursued on the inner side (Plate 19, fig. 7). When the surface of the creek is level with, or above low water, cradles are not required. In such cases, the ground is covered with a thin layer of clay, protected by an apron of fascine work. Plate 19, fig. 8, shows the state in which the openings are left, until the banks are completed. The material for the banks is taken from side cuttings, at least 20 feet from the foot of the slope, and each part undertaken is raised to its full height in one tide, the exposed side being covered with a thin layer of clay. In the next tide, this is provisionally protected by a 'crammat,' and before the ensuing spring tide, the work should be finally protected with stone, or wood.

When the banks are completed, the openings are closed in the following manner:—While the tide is down, the stone is removed from the apron on the outer side of the gap. The spaces between the wattles are then filled with strong clay well trampled down. On this is placed a layer of fascine work, about 10 feet wide and 1 foot thick, and to prevent percolation, a narrow trench is cut in its centre, which is filled with clay and sand mixed. The stones are then replaced. This should be all completed in one tide, and during the next, the inner side of the gap should be treated in the same way. The surface is thus brought up by degrees to the level of high-water neap tides. The whole width of the gap should then be raised in one tide above the level of the highest known tide, and all possible means should be used to finish the protection of the bank before the next spring tide. In order that the pressure may rest upon the inner, instead of the outer side of the embankment, the gates of the sluices are not opened, until the embankment is finally secured. When that is done, the water is allowed to run out of the inclosure and the reclamation is completed.

The Paper is illustrated by a series of diagrams, from which Plate 19 (figs. 1 to 8) has been compiled.

Mr. HAWKSHAW,—President,—remarked, that as the Papers which had been read were principally confined to the recital of practical details connected with an important class of Engineering works, they were not of such a character as usually led to a very extended discussion. Nevertheless there might be some gentlemen present, from whom it would be advantageous to receive any observations which they might have to offer, on the result of their experience in similar works.

Mr. VIGNOLES had practised the system described in the last Paper. It had been correctly stated by the Author, that the principal difficulty in reclaiming land did not consist in making the embankment, but in carrying it across the creeks and gullies, or deeper parts, where it was liable to sink, and to be breached. Until within the last seventy years, the mode of closing breaches, and of making the dams across these creeks, or gullies, adopted in most countries, was to proceed from both sides, by driving one, or more rows of close piling from each side towards the deepest part, until the aperture in the middle became so narrow, that the closing became gradually, more and more difficult to effect, and at last, from the great depth of water, was almost impossible. About a century ago, in consequence of the difficulties and failures which arose from its employment, it was found necessary to have recourse to some other method. The history of this subject as recorded in the archives of Holstein, Hamburg, and the Low Countries, was extremely interesting. Until 1789 the Engineers, who directed the works, considered it an innovation, to attempt to close a breach, otherwise than by piling across it. The more intelligent of the country people, however, contended that the best method was to use bundles of fagots, or fascines filled with as much gravel or broken brick as could be bound up in them. After this controversy had existed for some time, some of the leading Engineers had the common sense to adopt the suggestion of the country people, and eventually, they so far improved upon it as to produce, what might be considered as the perfection of the new system, namely, that of protecting the bottom of the gap, with an elastic covering of similar materials, but formed into what was now called a 'mattress.' Instead of narrowing the opening by working from the sides, they made it shallower, by laying the mattresses across the entire extent of the gap. They thus filled it up horizontally. In proportion as the bottom was raised, the velocity of the water was decreased, until a certain level was attained at which the velocity became so small as to enable them to close the breach without difficulty. Subsequently this system was almost universally adopted in Holstein and in the north of Europe. The employment of fascine work, or of bundles of bushes, mixed with gravel or broken brick, bound up tightly, and heavy enough to sink in a stream, and to remain in the position in which they were deposited, must have been common in Holland and the Low Countries, at a period of at least three centuries, before its revival under the preceding circumstances. These materials had probably been used in the first instance from want of stone, and had then been found to answer the purpose better. It was recorded that the Italian Engineers had used these materials about that period, and that they gave the fascines the name of 'salsiccias,' which was subsequently changed in the north of Europe to the present name of 'zinkstücken.' In the fifteenth century the Spanish Engineers also adopted the employment of these fascines for military and other works, the Italian name being retained under the French expression 'saucisson.' The system appeared, however, to have been forgotten in the Spanish Peninsula, as the old method of piling had been advocated there very recently. It was singular, that the art of employing fascines for closing breaches should have been neglected, until it was forgotten by the technical men in the Low Countries. No doubt its revival was due to some traditional idea on the subject, which had been kept up among the working class of the country people. In the great suspension-bridge, which Mr. Vignoles had erected at Kieff, in Russia, the piers and abutments were built on shifting quicksands, but they were protected for a breadth of 100 feet, by fascine mattresses, laden with gravel, stones, and broken bricks, and during the nine years, since elapsed, not the slightest movement of the masonry, or the wicker-work, had taken place. He had applied the same system to the stoppage and diversion of a large and deep branch of the River Ebro in Spain.

Mr. Gibbs said, that about forty years ago, he was sent to Holland, to learn Hydraulic Engineering. A variety of systems were then in use in that country, for closing up creeks, and breaches in banks. Of these the following method seemed to him to be the cheapest and most certain:—Two rows of piles were driven and properly braced together, so as to form the skeleton of a dam. The piles in each row were several feet apart, and horizontal planking was fastened to them, in such a manner as to leave alternate spaces for the passage of the water, the total area of these spaces being fixed at one-third of the cross section of the opening. This structure was erected before any progress had been made with the embankment, or otherwise the increased velocity of the water would have deepened the ground, between it and the terminations of the banks. The subsequent process of closing the embankment could be easily, and if necessary, rapidly effected. Commencing at the bottom of the gap, the spaces below, or at the low-water level, were first planked up, during the lowest tides, and the dam was filled in between with earth, care being taken to keep the surface of the portion completed as nearly level as possible. At each successive period of low water one, or more tiers of planks were added, and the centre of the dam was filled in as before. By raising the dam in horizontal layers, the velocity of the water was not accelerated, and when the necessary height was attained, the final inclosure could be made without difficulty. He had constructed an entire embankment upon the same principle. The material of which it was composed was so deposited, that at each tide, the top, as far as was practicable, presented a level surface, for the inflowing water to pass over, and the scour of the overflow was guarded against by temporary aprons. That work was successfully executed, and indeed he had never seen any difficulty in those cases where the horizontal system was adopted; while on the other hand, he had known instances, in which the cost of an undertaking had been nearly doubled, by attempting to effect the final inclosure, after the ends of the embankments had been carried so far forward, as to increase the velocity of the stream through the gap.

It had been stated that the ancient banks of Holstein had been carried away, owing to the percolation beneath the seat of the banks, and the consequent rising of the water within the inclosures. This view of the case did not accord with his experience and inquiries. When the sea was tranquil, there was usually a deposit of a muddy character left on the foreshore, which prevented percolation. The destruction of a bank, generally commenced by the water passing over the top, and scouring out a small channel on the interior slope. This rapidly enlarged its dimensions, until the amount of water which poured over assumed the character of a wave, and sapped the rear foundation of the bank. Breaches were rarely occasioned by the weight, or pressure of the water alone. It was, therefore, more natural to assume that the banks in question had been destroyed, in consequence of their being overtopped, by some of the heavy waves which broke upon those coasts, during gales of wind. According to the best information, the entire destruction of a bank was, in most cases, completed within less than half an hour after the first breach had been made.

As regarded the general question of the reclamation of lands from the sea, it was very difficult to separate the agricultural from the engineering branch of the subject. An Engineer was generally called upon to report upon the desirability of making the proposed inclosure, and some part of his observations must necessarily have reference to the value which the land would probably acquire, by being reclaimed. The lands most favourably situated for the purpose, and which would be likely to prove of the greatest ultimate value, were those within estuaries, and not those which were situated on the sea-coast, unless it so happened, that these were natural projections on the coast, which would have the effect of decreasing the motion of the water. When the tidal streams maintained their normal velocities, the deposit was in general very weak, and the soil of the foreshore did not, in consequence, contain the vegetable nutriment, which would give it agricultural value. When the tide met the fresh water stream of a river, there was usually a very rich deposit, containing a large amount of soluble organic and inorganic matter. The fertilising effect of the water of the Humber was due to this cause, and some lands, with a soil of this character, which had been reclaimed from the sea, or from the estuaries of rivers in England and in Holland, had successive crops taken off them, from time immemorial, without the aid of any further manure. There was a particular class of fine sandy deposit, of a siliceous character, which might easily be mistaken by inexperienced persons for mud, but upon examination, it would be found to contain so small a portion of soluble matter, as to render its inclosure a profitless speculation. This showed how desirable it was that Engineers, who undertook this class of works, should address their attention to the character of soil they were about to reclaim, because in some cases it might be worth while to inclose a small area with expensive works, while in others, however cheaply the works might be executed, the land when reclaimed might prove comparatively valueless.

Mr. **Giles** drew attention to the amount of material, which the Author of the last Paper had described as necessary for the protection of a bank, when its seat was below the level of half tide. The section (Plate 19, fig. 5) showed a thickness of 2 feet of clay, two courses of bricks, 5 inches to 8 inches of brickbats, and a layer of paving stones 12 inches deep, thus making a total protection of more than 4 feet in thickness. With this material, an upright wall of 12 feet in thickness might have been built, at the same cost, and it would have answered the purpose much better. His experience led him to the conclusion, that it was very difficult to close an extensive breach by the gradual contraction of its width. The best plan was to reduce the depth by cradles, and if necessary, as was sometimes the case, to widen the breach at the sides. The price at which the earthwork of the sheltered portion of the bank on Sunk Island (**A** to **B**, Plate 18, figs. 2 and 3) was stated to have been executed—namely, $4\frac{1}{4}d.$ per cubic yard—was extremely low.

Mr. **Brunlees** considered, that upright walls were not adapted for reclamation works, as the character of the land, on coasts, and in estuaries, was generally such, that suitable foundations could not be obtained for them. In the different localities, in which embankments had been executed under his superintendence, stone had been plentiful, and he had therefore used that material. He had usually adopted a slope of 2 to 1 for the sea face of the bank. The hearting was generally of sand, which was covered with a layer of puddled clay of 12 inches in thickness, and upon that, on the sea slope, was placed from 2 feet to 4 feet of 'quarry rid' and broken stone, and afterwards the pitching, which varied from 16 inches to 18 inches in thickness. By placing broken stone immediately under the pitching, the waves did not run so far up the slope, nor were they so destructive when receding. The water in the advancing wave was dispersed, through the joints of the pitching, and received into the rid. It was with the object of making the receiving power of the rid equal to the quantity of water likely to break upon the slope that its depth was varied from 2 feet to 4 feet. He had executed in Lough Foyle and in Morecambe Bay[1] about 13 miles of such embankments, which had already stood several years without any failure.

Mr. HEMANS said, that according to the statements put forward in the first Paper, it would appear, that in Holstein a great extent of the marshes, consisted only of a thin layer of soil, which had been deposited upon a substratum of peat, and that they floated on the surface of a bed of water, so that it was to be apprehended, that by their subsidence, large districts which had been reclaimed from the sea would ultimately be lost. No doubt those statements had been based upon careful inquiries, but a theory which involved the assumption, that a great portion of the magnificent domains recovered from the sea in Denmark and Holland, were resting upon large lakes of inland waters, was one, which demanded the most complete investigation. It was difficult to conceive a deposit of beds of solid peat, extending for miles, over a surface of water. If that water was the fresh water of inland lakes, and not the salt water of the sea, it was also obvious, that the mud on the surface of the peat, could not have been the result of deposits, from the mouths of rivers on the sea-shore; and even if it was admitted, that peat had formed upon the top of the water, and the soil had then been deposited upon the peat, it was reasonable to suppose that the process of cultivation would have rendered the peat tougher and harder, and not so liable to subside. The Author of the Paper had cited in illustration of his views, the remarkable incidents of the formation of the Zuyder Zee and of the Bies Bosch. It was worthy of consideration, whether those disasters had not been occasioned, by the breaking in of the banks, by high tides and storms, rather than, as the Author had suggested, by the subsidence of the inclosed land. Mr. Hemans considered, that those occurrences indicated the necessity for observing greater precaution, as regarded the conservation of the banks and foreshores; but if it was a fact, that thousands of acres were resting upon water, and that they were constantly subsiding, the apprehensions which had been expressed were well founded, and unhappily the impending evil was one which no engineering process could possibly avert.

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[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xiv., pp. 239 to 246, and 249.

All three of the Papers had treated of the reclamations being accomplished by banks with very flat slopes. He had considerable experience in the construction of railway embankments on the sea-shore, and had found that when stone could be procured, steep slopes were preferable. The water rose upon the slopes to which he referred from 12 feet to 14 feet, and at extraordinary tides it rose 17 feet. Mr. Dargan and Mr. McCormick, who had been engaged in numerous and extensive reclamations, entertained the same opinion, and had adopted steep slopes faced with stone. The stones did not require to be extremely large, or of great specific gravity, and if placed at a slope of 1½ to 1, or 2 to 1, they would afford a sufficient resistance to the action of the sea. When stones could not be procured in large quantities, the other methods of constructing and protecting banks which had been described in the Papers might prove very valuable.

Professor FORCHAMMER (of Copenhagen) had no doubt as to the correctness of the accounts, which had been given in the first Paper, of the actual state of the marshes in Holstein. As regarded their formation he explained, that the high land at their margin belonged to the newest tertiary period, and that towards the sea-coast they chiefly rested upon sand. The interior marshes, almost without exception, rested upon peat, which was often found in a compressed state, and in some cases reached up towards the high ground and covered its slopes. The outer marshes were considered to be the oldest formation, and the inner marshes the newest. The surface of all the older marshes in Holstein and Denmark, was at a lower level near the high land, than near the sea. The material forming the marsh had been deposited horizontally, but from the peculiar nature of the substrata, it followed that the portion of marsh which rested upon sand would not sink, as the sand could not be compressed by the weight of the marsh; while on the other hand, wherever it rested upon peat, a gradual subsidence had taken place. The difference of level, although not very great, was sufficient to render the natural drainage of the marshes a difficult operation.

There could be no question as to the fact, that a great part of the marshes, in Schleswig and Holstein, were alone supported by a substratum of peat, which floated on the surface of water. When borings were made into those marshes, water was found at depths varying from 6 feet to 12 feet, and in some cases at a depth of 20 feet. At first view such a state of circumstances would seem almost impossible, but it could be accounted for, if the peculiar manner in which the peat had formed was taken into consideration.

The conversion of a lake into a peat moss, was first commenced by the growth of plants with large leaves, principally of the genus 'Nymphæa' and 'Stratiotis.' Those large water-lilies threw up their leaves from the bottom, and gradually expanded, so as to cover the water, and to a certain extent shut out the air, thus promoting the increase of the under-water vegetation, so that at a later period, perhaps centuries afterwards, the spaces between the leaves were filled up, and the surface of the lake became entirely covered with moss. The peat itself was, however, formed from the decayed roots and leaves which fell from the under surface of the vegetation floating in the lake. Hence in process of time, there was a coating of vegetation and moss at the surface of the lake, and a bed of peat at the bottom. A lake in this condition was called a peat moss, but it was said to be 'unripe,' and if a man ventured upon its surface, it would be liable to break with his weight. There were thousands of peat mosses in this state, and there were others in which, by means of a further development of the same process, the whole of the water had been absorbed, and the former basin of the lake had become a firm peat moss, and in that state it was said to be 'ripe.' In the case of a very large proportion of the marshes to which reference had been made in the Paper, the peat moss had become ripe, or nearly so, before the superstratum had been deposited, and in those instances only a slight subsidence had taken place; but in the others the deposit had occurred while the peat moss was unripe, and while its surface was separated from the peat by a layer of water. At first a thin layer of clay must have been deposited at each high water, which entangled itself with the surface vegetation, and before the moss decayed, or the specific gravity of the floating mass had been sensibly increased, the superstratum must have assumed such a consistency that the upward pressure of the water was insufficient to break through it. It had been asked, how could the sea-water overflow these marshes? It was quite certain that the peat mosses under the marshes were fresh-water formations, and he was not aware, that there was any peat which had been formed from salt-water plants. But it must be remembered that in Denmark, as in England, there were many places along the shores where submarine forests were found. This indicated, that at some past time the land must have subsided below the level of the sea. From investigations he had made on this subject he was induced to believe, that the greater subsidences had taken place at a more recent period than that during which the inhabitants of Denmark used flint arms and implements, as these were found under peat moss, which had been covered by clay and marsh.

In answer to questions, Professor Forchammer explained, that the subsidence of the surface of an unripe peat moss depended upon, whether the weight of the moss was sufficient to force the water out from beneath it, through the surrounding soil. When the soil consisted of plastic clay, this pressure was very slowly exerted, but it existed wherever the marshes rested upon water. In the case of the Wilster Marsh, its surface had fallen far below the level of the sea, and the water was still being slowly pressed out, through and over the adjacent sands.

Mr. BIDDER (Past-President) concurred in Professor Forchammer's description of the formation, and present state, of the marshes in Holstein and Denmark. From personal observations Mr. Bidder was convinced, that 200 square miles, or 300 square miles of marshes between the Elbe and the Eider had been formed in that manner. The description was also equally applicable to many of the marshes in England, such as those of the estuaries in Norfolk and elsewhere; but the question of greatest interest, and that which had a more extended bearing as having reference to nearly all branches of marine Engineering, was the height and character of the bank which should be used to protect the inclosed land from the ravages of the sea. In Holland the banks varied in height from 10 feet to 13 feet, above the ordinary high-water level. In the Thames, and in the estuaries of Norfolk, a much less height was considered necessary, and the tops of the banks were usually placed only 4 feet above the ordinary high-water level An opinion had been enunciated, that the difficulties of making an embankment were not coincident with the area of the land to be reclaimed. The experience of the Netherlands Land Company with which he had been connected, pecuniarily and professionally, would however demonstrate the incorrectness of that proposition. The two first inclosures which they made were of 1,400 acres, and 1,080 acres, respectively; but although successful, they were works of some difficulty. The next inclosure attempted was 1,800 acres. At that time, instead of being Chairman, Mr. Bidder was Engineer to the Company, jointly with Mr. George Robert Stephenson (M. Inst. C.E.), and he protested against the attempt to inclose so large an area at one time, but nevertheless he was told, that on account of financial considerations, it was necessary to run great risks, and in consequence, the reclamation was proceeded with. The bank was continuous, and was 5 miles in length; its average height being from 18 feet to 20 feet; its average outside slope 4 to 1; and the average inside slope 1½ to 1. The whole of this large amount of work was completed, and the inclosure effected, in one summer. But unfortunately, in the following February, a very violent gale came on, from the north-west, which introduced a heavy sea into the estuary of the Schelde, and caused a high range of tide, so that although the bank had been constructed with its top at a level of 13 feet, above the ordinary high-water mark, the sea washed over it, and considerable damage resulted. The material of which the bank was composed, was ordinary silt, taken from the foreshore; but if that gale had not occurred for a year or two, the probability would have been, that no such accident would have taken place, because the turf would have formed, and the water would then have run off, without penetrating to the body of the bank. As it was, the protective effect of the bank was nullified, almost in an instant, as the sea rapidly washed away the light material of which it was formed. This disaster showed, how necessary it was, in the construction of this class of works, not only to insure their successful completion, but also to provide against all the eventualities to which they were subject. In Holland, where the foreshore banks were liable to occasional irruptions, there were special laws and expedients, by which the whole energies and resources of a district were brought to bear, so as speedily to remedy the ravages occasioned by exceptional storms. It was much to be regretted, that the Author of the last Paper had not referred to this subject in detail, as no one could tell when accidents might occur, or when the information brought before the mind on occasions like the present, might prove of the greatest practical utility. Alluding to the recent destruction of the Middle Level Sluice, Mr. Bidder said that the disaster was of such a character, as to require all the energies and talents of an Engineer to remedy it. About 140,000 acres of fertile land had been exposed to inundation. The sluice had been admirably constructed, but as no large area, in proximity to the sea, was absolutely secure from a similar accident, it had occurred to him, as an after-thought, that so large an extent of property should not have been allowed to be dependent upon one work only, but that a stop-gate, or some other precautionary work should have been placed about 100 yards, or 200 yards inside of the sluice. The President, Mr. Hawkshaw, in whose charge the works had been placed since the disaster had occurred, would however be more competent to speak upon this subject than himself, and he was sure, would improve the occasion by communicating the results which had occurred to his mind, in reference to the precautions to be taken hereafter.

Another branch of reclamation, was when the land was drained by pumping, and by the regulation of the water in excess. That system had been proposed in Norway, to the extent of inclosing 400 square miles or an area of more than 250,000 acres. The outfall was to pass over a cataract, and in its course, was to be diminished by contraction, at its low-water level, and by expansion, at its high-water level. By this means the low water would not be allowed to fall so low, or the high water to rise so high, as previously. A similar project, in which Mr. Bidder was interested, had been proposed on the shores of the Baltic, where there was no rise, or fall of the tide, and where only a small amount of inclosure was required to shut out the sea, all the subsequent operations being confined to pumping. The effect of embankments upon the régime of estuaries and tidal rivers was a matter which required the most careful consideration, but erroneous opinions were often formed on the subject. The Harbour of Wells, in Norfolk, had been maintained, for a long period, entirely by the flux and reflux of the tide, and a sufficient channel existed for the coasting vessels frequenting the port; but a reclamation had been effected, by the Earl of Leicester, which he feared would be attended with injurious results to the channel. On the other hand, in the valleys of the Yare and the Waveny, and the marshes between Norwich and Yarmouth, there were several large areas of land, which offered a favourable opportunity for enterprises of that character. The tide there, was almost imperceptible, and the land could be reclaimed by very simple expedients. But in that case the Admiralty had offered resistance to any reclamations, on the assumption, that the proposed works would interfere with the navigation of the Harbour of Yarmouth. The Papers which had been read were of great scientific, philosophical, and practical interest, and he trusted that some other occasion would arise, when the subject could be discussed at the length, and with the detail, which it deserved.

Mr. PATON, in reply, said that after the very clear exposition of Professor Forchammer, it would be unnecessary that he should notice the subject of the marshes of Schleswig and Holstein, further than to express his personal adherence, to the correctness of the statement which he had made in the Paper, that a great proportion of those marshes rested upon water. As regarded the amount of pressure which the water exerted upon the banks, he would call attention to the case of the Schelenkuhlen Bank (Plate 17, figs. 15, 16, and 17), where there was a thickness of 30 feet of peat bog below the level of the ordinary ebb tide. Now when the water rose 20 feet—which it had done—above the ordinary flood level, there was a pressure of nearly 60 feet head of water on the peat bog. At one time the current at this place ran, at the rate of 10 feet per second, and the pressure was so great that the water forced itself upwards on the inside of the bank. The system of building walls with steep slopes, which had been advocated in the course of the discussion, would have been quite inapplicable to that dangerous state of circumstances, but it had been remedied by throwing out projections, or groynes, and diverting the current; and with such success, that he believed those marshes were more secure at the present time than they had been for hundreds of years past. The other sections on Plate 17, showed the types of the ordinary slopes which were adopted in Holstein and Schleswig. Such slopes had been found to resist the greatest storm-floods, which had been known in Europe, for the last two thousand years, while there was no record of a steep slope which had resisted the action of the sea for a similar period. In most of the cases, where the banks had been injured, the waves had rolled over the top, and had undermined the footing on the inner side.

Mr. **Oldham** remarked, that in some parts of Yorkshire, and particularly in the neighbourhood of Hatfield, lying between the Trent and the Ouse, there were substrata exclusively of peat formation which, for the most part, had been silted over by tidal deposit. These were now converted into available districts of excellent land. The peat was of such a character, that it was almost impossible to stand upon it without causing a vibratory motion; and in consequence a correct observation, with a levelling instrument, could scarcely be obtained. In his Paper he had stated, that the area of the embanked portion of Reed's Island, might at any time be doubled;[1] and since then, having examined and reported upon it by direction of the Commissioners of Woods and Forests, he had discovered that it might be made more than three times its present extent. It was still growing larger, but at the expense of the neighbouring shore. The water of the Humber was so rich in deposit, that wherever a projection was made, or the necessary works were carried out, an accretion of new land was the almost immediate result.

Mr. **Muller**, in reply, said that he believed there were records which showed, that cradles had been in use in Holland, for the last two hundred years. It was not, however, stated by whom they were first invented, but circumstances rendered it very improbable that they had been introduced by foreign Engineers. Nevertheless, it was quite true, that the Dutch were much indebted to the Spanish and Italian Engineers, for the various drainage works which they had executed in Holland. A statue still existed of Caspar Roblis, a Spanish Engineer, who made several inclosures along the sea-shore; but it was to be remarked, that none of those were below the level of high water. Doubts had been expressed as to the correctness of the principle which Mr. Muller had laid down, that the difficulty of carrying out the works of an inclosure was not increased by the larger extent of the area to be inclosed. The case cited of the works executed by the Netherlands Lands Company, however, appeared to confirm his views, inasmuch as the larger inclosure of 1,700 acres was executed quite as successfully, and with no more engineering difficulty than the smaller one of 1,000 acres; its failure occurred after its completion, and in consequence of a gale of wind, which had occasioned an unusually high tide and a very heavy sea. A serious drawback, connected with the employment of stone for the protection of banks, was the great expense which must always be incurred for its carriage. Except when the bank was constructed at the low-water level, barges could not come sufficiently near. On one occasion, in Norfolk, he found that stone, which cost 1*s.* 2*d.* per ton at the quarry, cost 10*s.* per ton, before it was placed in the face of the bank. But notwithstanding this disadvantage, and the others pointed out in his Paper, it could not be denied, that where the outlay was not an object, stone was the safest, and also, that there were certain situations where such a protection was indispensable. The class of banks which he had described in the Paper, had existed in Holland from 30 years to 50 years. In illustration of the force, and the height of the waves on the Dutch coast, he would mention, that at Flushing, in the mouth of the Schelde, there was a vertical fortification wall, the coping stone of which was 18 feet above the high-water level, the summit of the slope of the earthen bank upon the top of it, being 8 feet higher; thus making in all a total of 26 feet above high water, and that the waves had frequently rushed over the top of this bank and seriously damaged the back slopes.

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[1] *Vide* ante, page 456.

From the statements made in the first Paper it would appear that there was some misapprehension as to the causes which had led to the formation of the Zuyder Zee and the Bies Bosch. It had also been stated that the area of the Zuyder Zee was 2,000,000 acres; whereas the chief Engineer of the Water Staat had computed the area of the whole inlet to be 1,370,000 acres. By deducting from this 370,000 acres, as the area of the Laauwer Zee, it would appear, that the area of the Zuyder Zee only amounted to about 1,000,000 acres. It had further been asserted, that this vast expanse was formerly a tract of fertile land, covered by towns and villages, which had been inundated by the sudden bursting through of the isthmus between Steveren and Medemblick. Its previous history, however, tended to prove that it was never thickly inhabited, and that in former times it consisted of bog and marsh land, studded with lakes and numerous channels, the progressive enlargement of which, by the successive encroachments of storms and tides, extending over a period of nearly eighteen centuries, was the cause of its eventually being covered by water from the sea. According to the earliest records, this tract of marshes and bogs had originally a communication with the North Sea near Petten, and a row of dunes or sand hills occupied the position of the present mouth of the Zuyder Zee. A lake called Flevo, having a surface of about 280,000 acres, also existed in the centre of the district. About ten years before the Christian era, when the Roman general Drusus connected the Rhine at Doesburgh with the Yessel, at Nestervoort, by the canal which was called by his name, the channel near Petten was fast silting up, and the encroachments of the sea on the dunes had formed several small outfall channels, which were the rudiments of the existing openings, or straits between the main land, and the several islands of Texel, Vlieland, Terschelling, and Ameland. It was a fact, that the marshes, in certain districts of the Low Countries, consisted of a superstratum of soil upon a layer of peat, which rested upon a bed of water only. The peat was often from 10 feet to 14 feet in thickness. The bottom of the Zuyder Zee was in many places peat, and there was every reason to believe, that large portions of the marshes which formerly occupied its area, floated upon water in the manner described, and that they had been broken up, by successive encroachments, and under pressure of the high tides and storms. The lumps detached had most likely been carried out to sea. The inundations of A.D. 350, A.D. 353, A.D. 695, and A.D. 733 widened out the channels alluded to, and further extended the area of Lake Flevo. In A.D. 814 a very heavy inundation took place, during which the land between the now existing island of Urk, and the coast of Guelderland disappeared. The enlarged expanse of water was then called Almare, which name it retained until A.D. 1170, when the remaining portions of the dunes, between the islands at the entrance, having been swept away, the salt water inlet, as at present existing, was formed, and it received the name of the Zuyder Zee. From one or two incidents, which had been recorded, it would appear that the Zuyder Zee had always been shallow. At the beginning of the twelfth century, the English Count Clanricarty bought the island of Rathlin, and one of his servants passed on foot over the sands between it and the shore, the distance being about 7 English miles; and in A.D. 1255, people were able to go from Enkhuisen to Stavoren by the aid of jumping poles.

The circumstances attending the irruption of the sea which formed the Bies Bosch, were widely different from those which resulted in the formation of the Zuyder Zee. The bottom of the Bies Bosch was sound clay, without any peat, and instead of the inundation being the progressive work of centuries, the whole tract of country was overflowed in a single night. On November the 14th, 1428, its surface was covered by seventy-two villages and numerous farms. In the course of that day a flood, called the St. Elizabeth Flood, rose to an extraordinary height, and breached the protecting bank of the district at a place near the present Moerdyk station of the Antwerp Railway, and before the morning the seventy-two villages were destroyed, and the Bies Bosch had attained its present limits.

Allusion had been made to an incident of a serious character which was of frequent occurrence in Holland. In certain places the protecting banks had a foreshore of salt marsh, with a river, in some cases 150 feet deep, running close to it. If the current impinged too strongly upon the foreshore, a sudden fall, or slip, was the consequence. When such an accident took place, the only remedy was to construct a new bank behind that which was endangered, and to protect the old bank, by cradles covered with stone. Close to the works of the Netherlands Land Company an accident of this sort occurred—a salt marsh which in the evening was above high-water level, before the next day sunk to about 40 feet below low water.

The system of closing gaps and breaches by piling and horizontal planking, which had been described in the course of the discussion, was a very old one. In Holland, it had been abandoned except in closing very small streams. All cofferdams were objectionable when used for such a purpose, owing to the water being liable to penetrate either under the bottom, or round the sides. Another method of closing up small streams was now in use. Faggots were laid in a slanting direction over each other; these were fastened with stakes and loaded with stones. From his own experience he believed, that by adopting the system of laying layer upon layer, horizontally, the largest breaches could be easily closed. Clay alone was an unsuitable material for the purpose. It was liable to crack and dissolve, and a great portion of it was generally washed away. Clay and sand combined resisted the action of the water much better. Between 1853 and 1860, he had successfully closed seven large openings, the greatest depth of which varied from 28 feet to 42 feet, below the level of high water. The size of the cradles need only be limited by the strength of the current, and the facilities which existed for sinking them. One of an acre in extent was sunk near Flushing about six years ago. In the progress of the works of the Norfolk Estuary, under the superintendence of Mr. Fowler (V.P.), he had sunk twenty-seven of these; the largest was 150 feet long, by 50 feet broad, and the smallest 90 feet long, by 30 feet broad. One of the closure holes was about 7 chains in width, and 24 feet deep, below low-water level. The cost of the cradles depended entirely on that of the brushwood, but 8*s.* per cubic yard, or 10*s.* per cubic yard, might safely be considered as the maximum.

In conclusion, he would submit to the consideration of the profession, whether the system of sinking cradles and covering them with 'pierre perdue' might not prove a more rapid, and economical mode, of constructing quays, breakwaters, and other maritime works, than any of the methods which were at present in use.

Mr. HAWKSHAW—President—said, that as only a few days had elapsed, since he had become connected with the works which were to be undertaken, in consequence of the bursting of the Middle Level Sluice, he did not think it would be wise, that he should express any opinion on that subject. No doubt the fullest investigation would be made into the cause of that disastrous occurrence, and when the necessary information was in his possession, he would, at a fitting time, lay it before the Institution.

The Papers were of a very valuable character, as they communicated the observations and experience of gentlemen who had been extensively engaged in works of reclamation, and in interposing barriers to the ravages of the sea—works which were always more, or less beset with difficulties. The most useful information the Institution could obtain, was the account of works which had been actually executed, or of those which had been attempted and failed. The question of the best slope and material for banks was one which had been repeatedly discussed; but it was evident, that the material must be selected in reference to its cost, and that the slope must be adapted to the material. Those, perhaps, were the only two general rules, which it was possible to lay down.

May 6, 1862.

JOHN HAWKSHAW, President,
in the Chair.

The following Candidates were balloted for and duly elected:—JAMES GRANT FRASER, HARRISON HAYTER, ALEXANDER MEADOWS RENDEL, JOHN EDWARD TANNER, JOSEPH D'AGUILAR SAMUDA, and CHARLES FITZWILLIAM WHITE, as Members; Major ANTHONY CHARLES COOKE, R.E., Captain WILLIAM HENRY MACKESY, CHARLES EDWARD WALKER OGILVIE, WILLIAM SUGG, DANIEL THWAITES, JOHN ROBSON WARHAM, and WILLIAM WEILD, as Associates.

The reading of the Papers, No. 1,065, "On the Sea Dykes of Schleswig and Holstein," by Mr. PATON, and Nos. 1,055 and 1,066, "On Reclaiming Land from Seas and Estuaries," by Mr. OLDHAM and Mr. MULLER, having been concluded, the Discussion upon them was continued throughout the evening, to the exclusion of any other subject.

May 13 and 20, 1862.

JOHN HAWKSHAW, President,
in the Chair.

The following Candidate was balloted for and duly elected on May 20, RICHARD JOHNSON, as a Member.

No. 1,070.—"The Malta and Alexandria Submarine Telegraph Cable."[1] By HENRY CHARLES FORDE, M. Inst. C.E.

THE object of this Paper is to describe the design, and the manufacture of the Malta and Alexandria Submarine Telegraph Cable, as well as the process of laying, which was completed on the 28th of October, 1861, under the direction of the late Mr. Lionel Gisborne and the Author, who were appointed the Engineers by Her Majesty's Government in May, 1859. To render this description clear, it is necessary to give a short account of some changes in the destination of the cable, previous to its adoption for the Malta and Alexandria line.

The first intention of the Government was to lay the cable, in the autumn of 1859, between Falmouth and Gibraltar; and on the 26th of May in that year, a contract for the core was made with the Gutta Percha Company. It was not easy, however, to decide on a design for the outer covering; and, in order to allow time for further experiments, the Government determined, in the month of July following, not to lay the cable during that year. In September, the forms of outer covering were settled, and tenders were advertised for, and on the 23rd of December a contract was made with Messrs. Glass, Elliot, and Co., for covering the cable, and for laying it between Falmouth and Gibraltar.

In Table I. (page 494) is given the specification for the cable designed for this line, with a core calculated to transmit five words per minute, and with different outer coverings suited to the various depths.

A proviso was made in the contract, that the cable might, if required, be laid elsewhere; and in March, 1860, the Government determined to use the cable to join Rangoon and Singapore, in order to avoid the risks attending a deep-sea route, and to secure the advantages of a more rapid communication with China. The necessity for this line was lessened by the Peace, concluded with

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[1] The discussion upon this and the following Paper occupied portions of two evenings, but an abstract of the whole is given consecutively.

TABLE I

FALMOUTH AND GIBRALTAR TELEGRAPH.

SPECIFICATION OF CABLE.

Description of Cable.	Core: Weight per Knot.			Outer Covering: Weight per Knot.				Number of Outside Wires.	Gauge of Outside Wires.	Total Weight per Knot of Cable.
	Conductor, 7-Wire Copper Strand.	Gutta Percha and Chatterton's Compound laid on in three coats of each.	Total Weight.	Best Petersburg clean Hemp Yarn Serving, steeped in best Archangel Tar.	Iron Wires.	Steel Wires.	Hemp Yarn Strands, steeped in best Archangel Tar, to be twisted round each Steel Wire.			
	lbs.	lbs.	Cwt.	Cwt.	Cwt.	Cwt.	Cwt.	No.	B. W. G.	Tons.
Shore End—No. 1.; 10 to 50 fathoms	400	400	7·14	10·18	120·62	..	..	12	No. 3	6·897
Ditto—No. 2; 50 to 100 fathoms	400	400	7·14	5·60	85·81	..	..	12	No. 5	4·928
Deep Water—No. 1.; 100 to 600 fathoms	400	400	7·14	2·00	33·56	..	..	18	No. 11	2·135
Ditto—No. 2; 600 to 2,700 fathoms	400	400	7·14	1·78	..	10·55	6·00	12	No. 14	1·274

China in the autumn of 1860. Moreover, the wreck of the 'Queen Victoria,' and other accidents, delayed the expedition, so that the proper season for laying a cable along the Malay coast was lost; and the Government, therefore, once more altered the destination of the cable, and determined, in January 1861, to lay it between Malta and Alexandria, where, in the summer of that year, it was successfully submerged.

DESIGN.—In May 1859, when the Government first determined to lay a telegraph cable from England to Gibraltar, a series of questions, on the form and dimensions of the cable, was submitted to the late Mr. Robert Stephenson and Sir Charles Bright. The former recommended a copper conductor, weighing not less than 300 lbs. to the knot, which, with a battery of 36 cells, he believed, would ensure a speed of from 15 words to 18 words per minute, through a distance of 1,100 knots. The conductor was to be covered with three layers of gutta percha, with Chatterton's compound between the layers; the thickness of the insulator to be $\frac{1}{8}$ to $\frac{3}{16}$ of an inch, making the outside diameter of the core a little over half an inch. As to the outer covering, Mr. Stephenson stated:

"However advisable, and, indeed, indispensable, iron may be for shallow waters, it is certainly not well adapted to great depths, and, indeed, is quite inapplicable to such a depth as that contemplated." (viz., more than 2,000 fathoms). . . . . "Iron is also a material which is liable to rapid destruction in sea-water from rust; and steel is liable to a similar objection, although quite admissible as regards strength. When either of these materials is employed, it should be enclosed with hemp, which not only protects it, to some extent, from rust, but, if properly combined, assists materially in increasing the strength. I am, however, of opinion, that neither of these is well adapted for a deep-sea cable, and have no hesitation, under proper precautions, in recommending a hemp covering in preference. . . . . When laid down in deep water, free from under currents, I am of opinion that a hemp-covered cable will be efficient; nor would the destruction of the hemp be a serious evil, though I think it would prove as durable as the gutta percha itself."

As to shallow water, Mr. Stephenson stated: "It will be evidently necessary to make special arrangements for shallow water, where an iron cable must be used of great weight, and composed of large wires, further protected by a coating of hemp and pitch."[1]

Mr. Stephenson's Report is too long to be embodied in this

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[1] *Vide* "Further Correspondence respecting the Establishment of Telegraphic Communications in the Mediterranean and with India," &c. &c. (In continuation of Papers presented June 29, 1858.)—Presented to the House of Commons by command of Her Majesty, in pursuance of their Addresses, dated June 30 and July 25, 1859. Page 161.

Paper, but the Author thinks it best to give the recommendations it contains as far as possible in Mr. Stephenson's own words.

Sir Charles Bright recommended[1] a core almost identical with the one adopted, which had been previously submitted by the Author and his partner to Her Majesty's Government; and Sir C. Bright considered this core capable of transmitting ten words per minute through 1,100 knots. He also recommended a strong covering of solid iron wire, tapering by degrees in its advance towards the deep sea, and for the greater depths, a combination of iron and hemp.

It will be seen by the specification in Table I. (page 494), that the views of Mr. Lionel Gisborne and the Author coincided, in many respects, with those of the above-mentioned Engineers; but they thought that the large gauge of wire proposed for the shore ends rendered any further protection unnecessary, and that it was not advisable to use hemp alone as a covering for a deep-sea cable.

Iron-covered cables, of three sizes, were designed for varying depths to 600 fathoms; and a cable covered with a combination of hemp and steel was designed for greater depths. The hemp and steel cable was to have been laid across the Bay of Biscay, for a distance of about 360 miles, where the depth varied from 600 fathoms to 2,700 fathoms. The novelty in this outer covering consisted in the use of steel wires, each enveloped in hemp strands, laid on spirally. Twelve of these formed the outer covering, giving the cable the general appearance of a hempen rope. Before recommending this new form of cable, the Government Engineers and Mr. Siemens made a series of experiments, the result of which proved, that the breaking strain of the steel and hemp-covered cable was equal to 11,000 fathoms of its weight in water; whereas an exclusively iron-covered cable would break with less than 5,000 fathoms of its weight in water.

The specific gravity of the new form was also much less than that of the old, and comparatively little strain would therefore have been required to keep it under control even in the greatest depths, avoiding much risk of damage, or total failure. A cable of this form was used to connect Toulon with Algiers, and, in some respects, it has answered admirably; but the hemp, which it was at one time thought would protect the steel wires from corrosion, is itself rapidly eaten away by insects, even in depths of 800 fathoms and 1,000 fathoms.

When the destination of the cable was changed, and the deep-sea line was abandoned, first for one route, and then for another in which the depths hardly ever exceeded 100 fathoms, the hemp and steel covering was necessarily given up. By that time the contracts had been let, and the manufacture had made considerable progress, and it was thought unnecessary to alter the three other forms of outer covering shown in Table I., although the design would probably have been different if it had been known from the first, that the greater part of the cable would be laid in comparatively shallow water.

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[1] *Vide* "Further Correspondence respecting the Establishment of Telegraphic Communications in the Mediterranean and with India," &c. &c. (In continuation of Papers presented, June 29, 1858.)—Presented to the House of Commons by command of Her Majesty, in pursuance of their Addresses, dated June 30 and July 25, 1859. Page 160.

As the manufacture of the cable proceeded, the question of protecting the outer wires was occasionally mooted; but some of the proposed remedies would have entailed danger to the core, and all would have caused great delay and expense, without any absolute certainty of success. The wires of the cable, as laid, are much larger than those of the Atlantic, Red Sea, and Mediterranean cables, which have been injured by corrosion; and a large size of wire will probably always be found, whenever it can be adopted, the best safeguard against decay. The core was originally designed to transmit seven, or eight words per minute between Falmouth and Gibraltar, a distance of 1,100 knots. This estimate of the rate of working was afterwards reconsidered, and only five words per minute were stipulated for in the specification; a considerably smaller speed than was expected by Mr. Robert Stephenson and Sir Charles Bright.

The conductor is nearly four times the size of that of the Atlantic, and more than twice that of the Red Sea cable.

There has been little difference of opinion entertained as to the best size of insulator. A thick insulator has always been thought advantageous, and the adoption of this opinion, in practice, has been mainly controlled by considerations of cost.

The following Table illustrates the increase which has taken place in the size of the cores of telegraph cables:—

TABLE II.

No.	Date of Manufacture.	Name of Line.	Length of longest Section.	Weight of Core.		
				Copper, per Knot.	Insulator, per Knot.	Total Weight of Core per Knot.
			Knots.	lbs.	lbs.	lbs.
1	Jan., 1857	Atlantic Telegraph.	2,000	107	261 G. P.	368
2	Aug., 1858	Red Sea and India Telegraph.	730	180	212 G. P.	392
3	May, 1859	Malta and Alexandria (Falmouth and Gibraltar) Telegraph.	600 1,200	400	400 G. P.	800

MANUFACTURE.—The contract for the manufacture of the cable was divided into three parts; first, a contract for the supply of the gutta percha covered wire, or core; secondly, a contract for the outer covering of the core; thirdly, a contract for laying, and maintaining the cable for thirty days after complete submersion. As previously stated, the first contract was made with the Gutta Percha Company, and the two latter with Messrs. Glass, Elliot, and Co., after public tender.

Respecting the manufacture of the cable, the Engineers laid down two main rules, which were adhered to as far as possible, until the final completion of the contract. First, the core and the cable were to be kept continually under water, both in the works, and on board the ships during the voyage, and until paying out was actually commenced. Secondly, the electrical tests were to be continuous, and were to extend from the commencement of the manufacture of the core, until the whole length of cable had been submerged thirty days. In carrying these rules into practice, the core, as manufactured, was placed in lengths of one knot in the canal, at the Gutta Percha Company's works, where it was kept from fifteen to thirty days, to allow time for the water to penetrate any imperfections, before it was officially tested. If found sound upon testing, it was wound round iron drums, in lengths of two knots each, and placed in tanks of warm water at a temperature of 75° Fahrenheit. After a lapse of from twenty-four to forty-eight hours, to insure its attaining an uniform temperature, it was removed to the pressure tanks, from which the air was exhausted. Water, at a temperature of 75° Fahrenheit, was introduced, and the core tested; a pressure of from 600 lbs. to 800 lbs. on the square inch was next applied; and, after this pressure had been continued for ten, or fifteen minutes, the tests were renewed. The electrical condition of the core improved under the pressure by about 10 per cent.

When the core was taken out of the pressure tanks, it was carefully examined by experienced men, who made good any surface imperfections, such as the air-holes which had been developed in vacuo, and under pressure. These air-holes were occasionally found to penetrate the two outer coatings of gutta percha; thus showing the importance of the careful testing, and subsequent examination, as well as the absolute necessity which existed for laying on the gutta percha by successive coatings—precautions which were the more imperative, as the cables were intended to be laid in deep water. As the examination proceeded, the core was wound from one drum to another. It was then carefully packed, and in that state was forwarded to the works of Messrs. Glass, Elliot, and Co., where it was at once placed in tanks filled with water, in which it remained until it was required for the purpose of putting on the outer covering. The improvement in the manufacture of the core of this cable over those which preceded it, was not confined to the increase of weight, already shown by Table II. (page 497); but it also consisted in using a superior and more uniform quality of materials, in the better manipulation of the gutta percha, and in the use of a greater number of separate coats. The cores of the Malta and Alexandria, and the Red Sea and India cables, owe some of their increased efficiency to the introduction of Chatterton's compound. The following Table gives the relative resistance per knot of the conductor and insulator of the three cables; the weights of the cores of which were given in Table II.

TABLE III.

Name of Telegraph.	Temperature.	Resistance per Knot, after One Minute, in Siemens' Units.		Ratio of Resistance of Gutta Percha to Resistance of Conductor.
		Copper.	Gutta Percha.	
	Fah. °	Units.	Millions of Units.	Per Knot.
Atlantic Telegraph	75	13·5	12	888,888 : 1
Red Sea and India Ditto . .	..	8·3	30	3,614,444 : 1
Malta and Alexandria Ditto .	..	3·65	120	33,000,000 : 1

By means of this table the improvement in the manufacture of the core of the Malta and Alexandria cable, can be clearly appreciated. The resistances of the three cores, given in the above table, were obtained by direct measurement from sample lengths. The third column shows that the insulation per knot of the Malta and Alexandria cable is ten times better than that of the Atlantic, and four times better than that of the Red Sea cable. The ratio of the resistance of the conductor to that of the insulator, given in the fourth column, determines the leakage which would occur during the actual transmission of signals, and in this respect the relative value of the three cables is represented by the numbers 1, 4, and 37. The core supplied latterly for the Malta and Alexandria cable was superior to the sample referred to in the table.

It was requisite that great care should be observed in making the joints of the core, of which there were about four thousand two hundred in the Malta and Alexandria line, as the slightest imperfection in any one joint would be attended with danger. Accidents have occurred to the cores of cables when passing through the serving and spinning machines; and it is to be feared, especially when cables have been made during the night, that workmen, not wishing to keep the machine idle for any length of time, have occasionally taken it upon themselves to repair any damage which the core may have sustained. In parts of the Atlantic cable which have been recovered, joints have been found, where thick sheet gutta percha has been roughly put on, without any attempt to make a sound joint. It is difficult to devise a system which would place it beyond the power of a workman to conceal an accident; and this difficulty is much increased, when work is carried on at night, or with undue haste. To guard against accidents of this character, night-work was not allowed, and the joints were made under the direct supervision of an assistant of the Government Engineers, both at the Gutta Percha Company's works, and at those of Messrs. Glass, Elliot, and Co.

Difficulties arose in keeping the cable permanently under water, even in the contractors' works, as the foundations of some of the tanks gave way, under the weight of the cable. The upper coils were in consequence exposed to the air, after having been wet. Water was pumped over the exposed coils for some time, until the frequent washing off of the oxide which formed on the iron wires rendered it desirable to abandon that process. When the pumping was discontinued, and the coils began to dry, the electrical tests showed a loss of insulation, which, becoming daily more considerable, occasioned great anxiety. A special investigation was instituted, and the coil which showed the most imperfect insulation —a length of 162 knots—was cut into three nearly equal parts, and was then coiled into a dry tank, where it was carefully tested. A loss of insulation, with increased resistance in the conductor, was thereby detected; indicating apparently an increase of temperature. The maximum average temperature, as calculated by the copper resistance, was 80° Fahr., while the temperature of the water in the tanks was not more than 57° Fahr. No similar phenomena had ever been observed previously; but the Author believes that this was the first occasion where a telegraph cable had been kept under water for any length of time, during its manufacture. From the uncertainty which prevailed on the subject, her Majesty's Government called in the assistance of Dr. William Allen Miller, Professor of Chemistry at King's College, London, who reported that, "These heating effects appear to have been due, not to any permanent chemical change, either in the composition of the insulating coating of the gutta percha, nor in that of the serving of hemp and tar; but were owing simply to the effects of oxidation upon the iron, at the ordinary summer temperature of the air, produced by the moistening of the cable with the water of the river, the slightly brackish nature of which increased the effect." Dr. Miller's opinion was supported by the following experiment, made by

Messrs. Glass, Elliot, and Co. Coarse iron borings were placed in a wooden box of about one foot in depth, and water at a temperature of about 40° Fahr. was poured over them. In a few hours the temperature, measured by thermometers inserted in the box, rose considerably; and, after an interval of thirty-six to forty-eight hours, attained a maximum which exceeded 100° Fahr. The rate and amount of rise in temperature were found to depend upon the frequency with which the iron borings were stirred up and watered.

LAYING.—In the first instance, it was thought desirable that, during the process of laying, the cable should be kept under water, even when on board ship. But this idea was, for a time, abandoned, owing to supposed difficulties, and to the apprehension that there would not be sufficient time to carry out the necessary arrangements. When the heating was first observed, a pumping apparatus was fitted up, which, it was thought, would answer the same purpose as the water-tight tanks. But, on the receipt of Dr. Miller's Report, the insufficiency and even danger attending the process of pumping became apparent; the Engineers insisted that the original plan of fitting the ships with water-tight cable tanks should be carried out; and the change of destination to the Mediterranean afforded the requisite time.

Two steam vessels were employed in laying the cable—the 'Malacca' and the 'Rangoon.' Each vessel was furnished with two cylindrical tanks, which were placed nearly amidships. These were constructed of plate iron, riveted and caulked in the usual manner. They were about 30 feet in diameter, and 15 feet in depth; and were each capable of containing 600 tons weight of cable, submerged in about 100 tons of water. The ships were each 2,050 tons gross register, and the greatest weight carried by either vessel was as follows:—

	Tons.
517·62 knots of cable	1,289
Water in the two tanks . . .	200
Cable tanks and machinery about	200
Coals for 18 days	400
Total	2,089 tons.

The Author, however, considers that the above was too heavy a load, and that a load of about 1,700 tons was as much as either vessel was capable of carrying with safety.

The shipping of the cable was performed expeditiously, and as much as 90 knots of cable were put on board one of the ships in twenty-four hours. During the shipment there was only one casualty, and that of a trifling character. A fly-wheel came off the winding engine, and fell down the hold on to the cable, the top coil of which it partly indented. This part was cut out, although the tests did not denote that any damage had been done electrically. The height of each coil was about 12 feet or 13 feet, reaching to within about 2 feet of the top of the tank. The tanks were carefully decked over with planks, caulked and made water-tight, and means were provided for emptying and filling them when requisite. The eye of each coil was fitted with an open framework of timber. By this arrangement a fault which was discovered was cut out of the centre of a large coil, without its being necessary to uncoil the whole cable, as would have been the case with a solid eye; and thus the tedious and dangerous process of uncoiling in a hot climate was avoided. The coil alluded to was 223 knots in length, and was in one of the tanks on board the 'Rangoon.' The contractors' electricians had tested it for about ten days in the harbour at Malta, and were on the point of handing it over to be officially tested by the Government electricians, when something peculiar was observed in one of the last tests, which further investigation proved to arise from a decided fault. Electrical measurements showed this fault to be about two-thirds from the top of the coil. A man descended into the eye of the coil, and by counting the number of flakes, approximately found the position of the fault. The cable was then cut, and the tests proved that the top portion of the coil—a length of 157 knots—was free from fault. To save time, no precise measurements were made; but the cable was again cut at a distance of between 5 knots and 6 knots below the first cut, so as to include the fault in the severed length. The bottom flake of the top portion of the coil, and the top flake of the under portion of the coil, were then joined together, so as to form one circuit, leaving the faulty portion excluded, the ends of which were sealed up. This process only occupied a few hours, at the expiration of which the coil was again placed in safety under water. The faulty portion could not, of course, be then removed; but, subsequently, when that was done, the actual position of the fault was ascertained to be within a length of a quarter of a knot from the first cut. It was examined in the presence of representatives of the Government, of the Gutta Percha Company, and of Messrs. Glass, Elliot, and Company. No sign of violence, or peculiarity, could be discovered on the outside iron wires; but when they were stripped off, the core was found to be deeply indented; some of the hemp had been forced into the gutta percha, and some of the fibres were frayed. The injury had clearly arisen from a bruise, which must have occurred after the core had been served with the hemp, and before it was covered with the wire. After the heating which has been previously alluded to had taken place, the tests of this section of the cable had shown a low insulation resistance; but no signs of a definite fault had been reported until after the cable was shipped on board, and it had been again tested under water. Messrs. Siemens then reported, on the 14th August, 1861, that the tests were not satisfactory; and the Author, in consequence, stopped the departure of the vessel. On the succeeding day Messrs. Siemens, however, informed the Author that the tests, although not so high as could be wished, were not such as to justify the detention of the vessel, and she was allowed to leave.

A curious phenomenon occurred afterwards in testing the cable on board this ship. During the insulation tests marked jerkings of the galvanometer needle were observed, such as might have been caused by a fault. The origin of this unsteadiness of the needle was investigated by the Author, and by the electricians of the Government and of the Contractors. It was traced to two causes, both occurring in the batteries. By shaking the batteries it was found that these jerks could be reproduced. Part of the effect was traced to the looseness of the connecting screws; but, upon this defect being remedied, it was still found that, by shaking the battery, sensible jerks were produced; and, after some further consideration of the subject, the jerks were finally attributed to the disturbance of the gas which adhered to the plates of the battery. This explanation was supported by the fact, that the jerks were not observed when the batteries were in good order, in which case little, or no gas accumulates on the plates of a Daniell's cell; but when a battery has been in use for some time, gases, due to local action, are disengaged to a considerable extent. They adhere at times to the plates, and give rise to an electromotive force, opposed to that of the battery. Any disturbance of these gases greatly affects the force of the battery, so that in making delicate tests of a cable, it becomes of importance that the batteries should be in thoroughly good order.

After it was decided that the cable should be laid between Malta and Alexandria, instructions were sent, in January, 1861, to the Admiral on the Mediterranean station, to cause all the necessary soundings to be taken, on and about the line on which it was proposed the cable should be laid. Captain Spratt, of Her Majesty's surveying vessel 'Medina,' was intrusted with this work, and for a short time had the assistance of Her Majesty's surveying vessel 'Firefly,' under the command of Commander Maunsell. From the result of the surveys it was ascertained that the Admiralty charts were in parts incorrect; and that the soundings which were laid down upon them gave a deceptive idea of the general depth, and the conformation of the sea bottom along the proposed route. The line of coast was in some parts as much as 4 miles out of its proper latitude. In one instance a depth of 800 fathoms was found in long. 27° E., at about 6 miles from the coast, where the Admiralty Chart showed no greater depth than 65 fathoms, although several soundings were marked upon it in that locality. In another instance, in about long. 21° 20′ E., the Admiralty Charts gave 19 fathoms at 2 miles from the coast, 48 fathoms at 8 miles from the coast, and 70 fathoms at 12 miles from the coast; whereas Captain Spratt found, in the same longitude, as much as 435 fathoms, at a distance of only 2 miles from the coast. When the Author arrived at Malta, in March, 1861, it was supposed that sufficient soundings had been taken for the purpose of laying the cable; and it was contended that it would not be right to incur a further expenditure of time and public money; but when the cable was understood to be Government property, the Author's representations as to the necessity for a more extended examination of the proposed route were attended to, the surveys and soundings were continued for five months longer, as many as three of Her Majesty's ships were employed in the examination of one portion of the proposed line, and the survey, when eventually completed, was of such an accurate character as to enable the route to be carefully selected, and to be strictly adhered to. The Author submits that the proceedings in this case illustrate in the strongest manner the absolute necessity which exists of making proper preliminary surveys for telegraphic purposes, and of the extreme caution which should be used in determining the details of a route by means of the Admiralty Charts.

The 'Malacca' arrived at Malta on the 14th May, 1861, with the first portion of the cable in good condition. The tanks had sustained the strains incidental to a stormy passage, but no difficulty had been experienced in keeping them full of water. The testing had also been carried on during the voyage, except for a short interval, when it was discontinued in consequence of the captain complaining that it affected the vessel's compasses.

On the 28th May, 1861, the paying out began from Malta. Each ship was fitted in the following manner:—A large V sheave, furnished with a small friction break, was suspended over the centre of each hold. The cable was led over this sheave, and was prevented by the small breaks from acquiring too great a velocity before arriving at the paying-out gear, placed on one side of the stern. This apparatus consisted of three V guide sheaves, a break-drum, a dynamometer, and a stern wheel. The three V sheaves, 3 feet in diameter, were each furnished with a friction-strap, working in water, and were all placed in one vertical plane, parallel to the centre line of the vessel. The cable was passed over these sheaves and under three weighted jockey pulleys riding upon them. It next took three or four turns round the large break-drum, 7 feet in diameter. It then passed over a fixed sheave of about 3 feet 6 inches in diameter, and under a moveable weighted pulley, into the sea over a fixed stern-wheel also of 3 feet 6 inches diameter, placed at the level of the last sheave. The moveable pulley was placed half way between the fixed sheaves, at a distance of about 9 feet from each, and it worked in vertical guides. Upon these guides a scale was fixed, to correspond with an index on the moveable pulley, which denoted the strain to which the cable was subjected. This dynamometer was, in fact, similar to that used on the occasion of the successful laying of the Atlantic cable. The machinery was controlled by one breaksman, who was stationed near the dynamometer, and received his orders from the superintending Engineer. The controlling power was exercised through the medium of a spoked wheel, similar to a ship's steering-wheel; and by means of a pall and ratchet, the breaksman was prevented from inadvertently increasing the strain, since this could not be done unless he first released the pall.

In submerging the cable it was considered indispensable by the Author, first, that all abrupt transitions of depth should be avoided; secondly, that shore end cable, No. 1, should be laid wherever the bottom was rough, or the water was shallow; thirdly, that along the African coast the cable should be laid between the 100 fathom and the 30 fathom lines. The sections of the routes upon which the cable was actually laid (Plate 21, Figs. 1, 2, 3) will show to what extent these rules were carried into practice.

The first portion of the line was laid between Malta and Tripoli, and here the greatest depth along the whole line between Malta and Alexandria occurred, namely 420 fathoms. On the afternoon of the 27th of May the shore end of the cable, weighing nearly 7 tons to the knot, was landed in a sheltered bay on Marsa Scirocco, on the east end of the island of Malta. Soon after midnight of the 28th, a moonlight night, the 'Malacca,' accompanied by Her Majesty's surveying vessel 'Medina,' under the command of Capt. Spratt, got under weigh, and proceeded towards Tripoli, paying out the cable. The 'Medina' took up a position a short distance ahead, and steering upon the previously agreed course, served as a guide to the 'Malacca.' H.M.S. 'Scourge,' commanded by Commander (now Captain) Jones, also formed part of the expedition, and had been despatched several hours in advance, so as to arrive before noon of the following day at a fixed position about 70 knots from Malta on the edge of the Lampedusa Bank, where it had been previously arranged that the cable should cross the 100 fathom line of soundings. About 1h. P.M., the 'Scourge' was observed from the 'Malacca,' right ahead. At

3h. 20m. P.M. the 'Malacca' passed close to a buoy laid down by the 'Scourge,' and signalled to be in 90 fathoms. This sounding, when compared with the number of miles run by the 'Malacca,' and the amount of cable paid out, served to fix the position accurately. As the shallow water portion of the section commenced at this point, the ship was steered for a short distance in a winding direction, making a curve in the form of the letter **S**, so as to facilitate the raising of the cable in the event of its requiring repairs. Up to this time the cable was paid out at an average rate of 4·94 knots per hour, and the estimated slack paid out in the deep water was not quite 5 per cent. The maximum strain to which the heavy shore-end was subjected was 20 cwt., but with the main, or deep-sea cable the strain did not exceed 12 cwt. even in the greatest depth, which, as before stated, was 420 fathoms.

From this point to Tripoli a rather circuitous route was taken to the westward, in order to keep in a depth of water under 100 fathoms. This was accomplished except for a distance of a few miles, where a depth of 153 fathoms was reached. About 50 fathoms was the shallowest water in which this portion of the cable was laid. The steepest gradient was 1 in 17 for three knots, and no difficulties of any kind occurred, until attempts were made to splice the main cable to the Tripoli shore-end, which had been previously laid by another ship, its end having been sealed up, and left at a spot where the depth was about 30 fathoms. Nine unsuccessful attempts to complete the joint were made, owing to bubbles forming under the fresh gutta percha, but after cutting off a length of 25 fathoms of the shore-end, a perfect joint was completed. The bubbles burst the gutta percha during the making of the joint at different stages of completion, the first failure occurring almost immediately after the first layer of gutta percha was put on, and the last when the joint was nearly completed. It was the opinion of the Author and of the contractor's Engineer, that the difficulty arose from moisture having reached the conductor. A similar difficulty afterwards occurred in joining two lengths of cable, one of the ends of which had also been sealed up and placed under water; and in the evidence of Mr. Preece, given before the Joint Committee on the Construction of Submarine Telegraph Cables, several other instances of a like character are mentioned.[1]

After the completion of the first section, the cable remaining on board the 'Malacca,' a length of 290 knots, was laid from Tripoli in the direction of Benghazi. It was intended that the cable should be laid within the 100 fathom line, but that depth was exceeded in parts, owing to currents which took the vessels out of their intended course during the night. The maximum depth attained was 150 fathoms, the average speed of paying out was 5·3 knots per hour, and the greatest strain was 9 cwt. The end of the cable was sealed up and dropped in 30 fathoms, and remained there untouched for nearly four months. No deterioration of the insulation occurred during that time.

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[1] *Vide* "Evidence given before the Joint Committee on the Construction of Submarine Telegraph Cables," Questions 2,723 to 2,734 inclusive.

The cable next laid was part of the third section, beginning at Alexandria, and extending nearly 300 miles to the westward, towards Benghazi. This was the most difficult part of the whole line, owing to the roughness and irregularity of the bottom; but by carefully selecting and laying out the route to be pursued, after accurate soundings had been made, and by only paying out in daylight, it was successfully completed. Unless the route had been carefully laid down and strictly adhered to, the depths passed over might suddenly have varied from 50 fathoms to 500 fathoms, or more, so that many miles of cable might have been lost, and what is of more consequence, the permanence of the cable when laid might have been seriously endangered. This cable was laid by the 'Rangoon;' and the naval Commander-in-Chief of the station, Sir W. F. Martin, directed three of Her Majesty's ships to assist. The route consequently was selected, and the cable was laid with almost as much care as is usually bestowed upon the selection of the route for a railway through a difficult country. Her Majesty's ships throughout the operations were actively employed from daylight to dark. A number of buoys with flagstaffs were provided, and two of these vessels were kept constantly engaged in laying the buoys down and picking them up, or in taking soundings to guide the Engineers in their operations. At 5 A.M. on the 6th July, 1861, the 'Rangoon,' deeply laden with cable, began paying out from Alexandria. After 11½ knots of the heavy shore-end cable had been laid, main cable to the extent of 55 knots was paid out; the heavy cable was then again resumed, shortly after which, at 9 P.M., the ships came to an anchor in 27 fathoms water, having paid out 67 knots of cable, at an average speed of 4 knots per hour. At 7 o'clock the next morning the work was resumed, and was continued until 5·30 P.M., when 35½ knots of heavy cable, and 11 knots of light cable, had been paid out, at an average speed of 4·23 knots per hour. On the third day, owing to the great irregularities in the depth, only 26½ knots of cable, including 9 knots of heavy cable, were paid out. To enable this to be done, the vessels in attendance were obliged to take frequent soundings, and ten buoys were laid down, at an average distance between each buoy of about 2½ knots, but the bottom was so irregular that some of these buoys were obliged to be placed at a distance of half a knot apart. The average speed was 4·11 knots per hour, and the time actually employed in the operation was about seven hours. On the following day, 32¾ knots of cable, including 21¾ knots of heavy cable were laid, at an average speed of 4·09 knots per hour, five buoys being laid down, and in addition, many of the positions were marked by the ships in attendance. Eight hours was the time actually employed by the paying-out ship. On the fifth day 45 knots of heavy cable were laid, in ten hours, giving an average of 4·5 knots per hour. On the sixth and last day, 62⅓ knots were laid in 11 hours 45 minutes, giving an average of 5·44 knots per hour. The end was then sealed up, and dropped in a depth of 30 fathoms. It was not buoyed, but a flag-buoy was left near the spot, and good bearings were obtained. Thus, six days were occupied in laying 128·8 knots of heavy cable and 153·32 knots of main cable, or a total length of 282·12 knots. Thirty-two buoys were laid down, and numerous positions were also marked, by the assisting ships. Upwards of sixty different courses were run. The maximum depth of water was 102 fathoms; the minimum, for a short length, on a sandbank where a heavy cable was laid, was 13 fathoms, and the average was 33 fathoms.

The quantity of cable laid per day may be taken as an index of the ease, or difficulty with which the work was done. It was at first feared that anchoring each night might be inconvenient, and be attended with danger to the cable; and on one occasion a kink was actually made in the cable immediately after anchoring, but this accident might probably have been avoided by using greater precaution until the ship had swung head to wind. The kink was, however, cut out, and an opportunity was thus afforded of separately testing the portion of the cable laid down and that still remaining on board the ship. No other accident, or inconvenience of any kind occurred.

Subsequently, the second part of the third section between Alexandria and Benghazi, was also laid from the 'Rangoon,' beginning on the 20th September at the buoy left by the same ship, and ending on the 24th September at Benghazi; and, finally, the second part of the second section between Benghazi and Tripoli was laid, from the 'Malacca,' beginning on the 26th September at the place where the cable had been left on her first trip, and ending at Benghazi on the 28th September, 1861, when the telegraphic communication between Malta and Alexandria was successfully established. To describe in detail the laying of these sections would only lead to tedious and useless repetitions. It will be sufficient to notice that the steepest gradient in the second section was 1 in 50 for three knots, and in the third section 1 in 28 for two knots.

The laying of the cable was eminently successful as a mechanical operation. The paying-out machinery worked evenly and with great precision, and reflected much credit on Messrs. Canning and Clifford, the engineers to the contractors. The breaks, with the exception of a few instances, when the heaviest cable was being paid out into rather deep water, were relieved from all weight, and it was evident from the appearance of the cable passing over the stern of the ship, that sufficient slack was being paid out to preserve the cable free from tension, and to insure its resting upon the bottom. No accurate estimate could be made of the actual slack paid out, but as a general rule in depths under 100 fathoms, from 2 to 2½ per cent. was the utmost that could be got out of the ship when the cable was running quite free. This, however, taking into account the comparative evenness of the bottom, must be considered ample, as it corresponds to gradients of 1 in 5 and 1 in 4·4. The angle at which the cable was paid out ranged from 40° to 45°. The maximum speed was 7·15 knots per hour, the minimum 4·5 knots per hour, and the mean speed was 5·25 knots per hour.

The landing-places were carefully selected in localities which vessels did not use as anchorage grounds, and where the cable was not liable to be worn away by attrition. Owing to the nature of the coast the landing-place at Benghazi was not so satisfactory as could have been wished; but lengths of spare shore cable have been left in store, so that repairs, if required, may be effected without delay. The ends of each of the sections of the cable were brought under ground into well-constructed houses, large enough to enable testing to be conducted inside. To guard against damage by lightning, dischargers were placed inside each house, between the cable and the air wire connections with the office, and lightning conductors were put on each post of the air line. Underground connections, made with the surplus cable, have since been substituted for the air lines at several of the stations, and danger from lightning is thus entirely avoided.

Respecting the tests, during and after the laying of the cable, the Board of Trade, at the instance of the contractors, decided that the tests during the period of submersion should be made by the contractors' electricians only. This is to be regretted, as the system they adopted in making the tests differed from that by which the Government tests were made. After the completion of each section the testing fell again into the hands of the Government electricians, and the operations were continued for at least thirty days. Figs. 1^a, 2^a, 3^a, Plate 21, show the results of the contractors' and the Government tests on the three sections—1, 2, and 3 respectively. By these it will be observed that as the cable was paid out, its electrical condition invariably improved. The amount of improvement depended, chiefly, on the difference of the temperature of the cable before and after it was laid. Pressure also improves the insulation of a cable, and every hundred fathoms of water would produce from that cause alone an increased resistance of about 2 per cent.

In the first, or Malta and Tripoli section, the insulation resistance per knot rose from 160 units to 290 units, or 81 per cent. The temperature in the hold varied from 66° Fahr. to 72° Fahr., and the final resistance of the submerged cable, after allowing for an improvement of 7 per cent., as due to pressure, corresponded to a mean temperature of 63° Fahr. The mean resistance of 245 units, observed during the Government tests at a warmer time of the year, corresponded to a temperature of 64° Fahr.

It has already been stated, that immediately after the laying of the Malta and Tripoli section had been completed by the 'Malacca,' the 288 knots of cable on board that vessel were laid from Tripoli towards Benghazi, so as to form part of the second section. The water that surrounded this coil on board the ship had been drawn off a few days previously. Its insulation resistance, after one minute's electrification, had consequently fallen to 86 units per knot, representing a temperature of 79½° Fahr. The resistance gradually improved during the laying, until the final test showed a resistance of 318 units, or an improvement of 258 per cent. This resistance, after deducting 5 per cent. for improvement due to pressure, corresponds to an average temperature of 61° Fahr. At the deepest part of this line the temperature observed was 59° Fahr. and 60° Fahr. The average depth was 85 fathoms.

As previously stated, the second part of the second section was laid three months afterwards, when the 265 knots of cable then on board the 'Malacca' were joined to the 288 knots already laid. The insulation resistance per knot after two minutes' electrification of the 288 knots, was 243 units, and that of the 265 knots was 59 units. The temperature of the hold varied from 76° Fahr. to 81° Fahr. The mean resistance of the two portions, when joined into one length of 553 knots, was 100 units. When the whole length was laid the mean insulation resistance increased to 200 units per knot. To effect this change, the portion last laid must have improved 176 per cent., and its resistance per knot must have been 163 units, equal to a total resistance of 744,000 small units. The Author believes this result to be somewhat below the truth, for the official tests showed, that this part of the cable, after two minutes' electrification, had a resistance per knot of 214 units; and after one minute's electrification, of 195 units. The contractors' tests correspond to a temperature of 68° Fahr.; the official tests to a temperature of 67° Fahr. The temperature of the surface water during the paying-out was 75° Fahr.

The first portion of the cable, laid on the third section, was 282 knots in length. When tested at Alexandria its resistance per knot was 56 units. The temperature on board the ship was then only 80° Fahr.; the water in the harbour, at the same time, however, was about 85° Fahr., a temperature corresponding more closely with the low state of insulation indicated. As there was no other indication of a fault, the low insulation was attributed to the temperature; and the contractors, considering their tests satisfactory, did not hesitate to proceed with the laying of the cable, especially as the depth of water along the route on which it was proposed to be laid did not exceed 60 fathoms. As previously stated, six days were employed in laying this portion of the cable, and during that time the cable was carefully tested, and the indications were attentively watched. As the water along this section was shallower, and therefore warmer, than along any of the sections previously laid, no great improvement in the insulation was expected. While the first thirteen knots were being paid out, a trifling lowering of the insulation was observed. This was due to a rise in the temperature of the cable in the tank, which had been emptied of water when the laying commenced. Subsequently a steady, but very gradual improvement took place, until the final test, after laying, showed that the insulation had risen to 106 units, an improvement of about 90 per cent.; the average temperature of the water thus indicated was about 75° Fahr. As before noticed, the end of this length of cable was sealed up and left in a depth of 30 fathoms, and the section was not completed until after more than three months had elapsed. On picking up this end and testing the cable, it proved to be in the same condition as when it was first laid. A length of 323 knots of cable was then spliced on, making in all 605 knots in circuit. After two minutes' electrification, the 605 knots had an average resistance per knot of 75 millions of units, and this gradually improved during the operation of paying out, to 120 millions, or 60 per cent.

The improvement of the last portion laid amounted to 177 per cent., and its final total insulation resistance was 685,000 small units, or 180 large units per knot, which corresponded to a temperature of about 70° Fahr. During the thirty days' official tests, this section gradually improved as a whole to the extent of 33 per cent. This was, no doubt, in a great measure attributable to the cooling of the water during the fall of the year. The mean of all the one minute electrification tests gave 250,000 small units, as the total of the whole section, or 149 large units per knot, which corresponds with an average temperature of water of 71° Fahr.

The Author proposes only generally to notice the results connected with the official tests of the cable, leaving the details of the testing, and such further explanations on the subject as may be necessary, to be brought before the Institution by Mr. Siemens.

The insulation of the several sections, when tested by the final official observations, extending over thirty days, corresponded with one another, and also with the tests made on sample knots which had never left the Gutta Percha Company's works. The highest resistance was found in the deepest and coldest water, and the lowest in the shallowest and warmest water.

The final results of the official tests are shown in the following Table:—

TABLE IV.

Number of Section.	Mean Insulation Resistance per Knot, after One Minute's Electrification.	Corresponding Temperature.	Mean Depth.
	Large Units.	Fahr.	Fathoms.
Section No. 1	245	64°	133
Section No. 2	195	67°	71
Section No. 3	149	71°	47

Unfortunately, the temperature of the cable when laid could not be calculated from the resistance of the copper, owing to the interference of earth currents; and it was impossible, by direct observation, to obtain the mean temperature of the line at any time along its whole length. The correspondence between the tests made by the contractors and those of the official Engineers' tests is quite as close as could be expected from observations made by different methods, at different seasons of the year.

Table V. (page 513) shows the results of a few experiments in the rate of working through the different sections of the cable.

In reference to this Table it must be remarked, that it is at all times difficult to arrive at any definite measurement of telegraphic speed, as it depends, to a great extent, on the skill and experience of the clerks, the construction of the instruments, and the condition of the batteries. The results given must, therefore, only be taken as the nearest approximation which could be arrived at after a few days' trial. It was stated in the first part of this Paper[1] that the speed expected through 1,100 knots was five words per minute. It will be noticed that column 11 is computed in accordance with that estimate. The speed actually attained agrees very fairly with the figures in that column, except in the short sections, where the limit of the speed is necessarily determined by the skill of the clerk.

Amongst the other improvements developed in the details of this undertaking the Author would draw attention to the small amount of battery power employed, namely, one cell to each 100 knots,

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[1] *Vide ante*, p. 497.

TABLE V.

Number of Section.	Name of Section.	Length.	Battery Power.		Speed actually obtained in Words per Minute (5 letters).					Estimated Speed in Words per Minute (5 Letters).
			+ No. of Cells.	− No. of Cells.	1st Trial.	2nd Trial.	3rd Trial.	4th Trial.	Mean.	
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
No.		Knots.	No.	No.	No.	No.	No.	No.	No.	No.
1	Malta-Tripoli	230	3	2	27·3	20·7	..	..	24·00	45·7
2	Tripoli-Benghazi	507	4	3	..	..	..	..	14·00	16·9
3	Benghazi-Alexandria . . .	597	6	4	..	..	..	..	12·00	13·4
1, 2, & 3	Malta-Alexandria	1,330	12	10	3 33	3·07	3·60	..	3·33	3·62
1, 2, & 3	Malta-Alexandria	1,330	15	12	3·75	3·00	2·40	3·00	3·04	

whereas twenty-five cells to each 100 knots were at one time recommended for the Red Sea cable. He considers it a matter of congratulation, that no injury to the insulation need now be feared from the feeble currents used in signalling. In conclusion, he hopes, that the practical details of the Malta and Alexandria cable, however imperfectly they may have been laid before the Institution in the present Paper, may not be without useful results, in affording data for more important and extended advances in the science and art of submarine telegraphy.

The Paper is illustrated by a map and diagrams, from which Plates 20[1] and 21 have been compiled.

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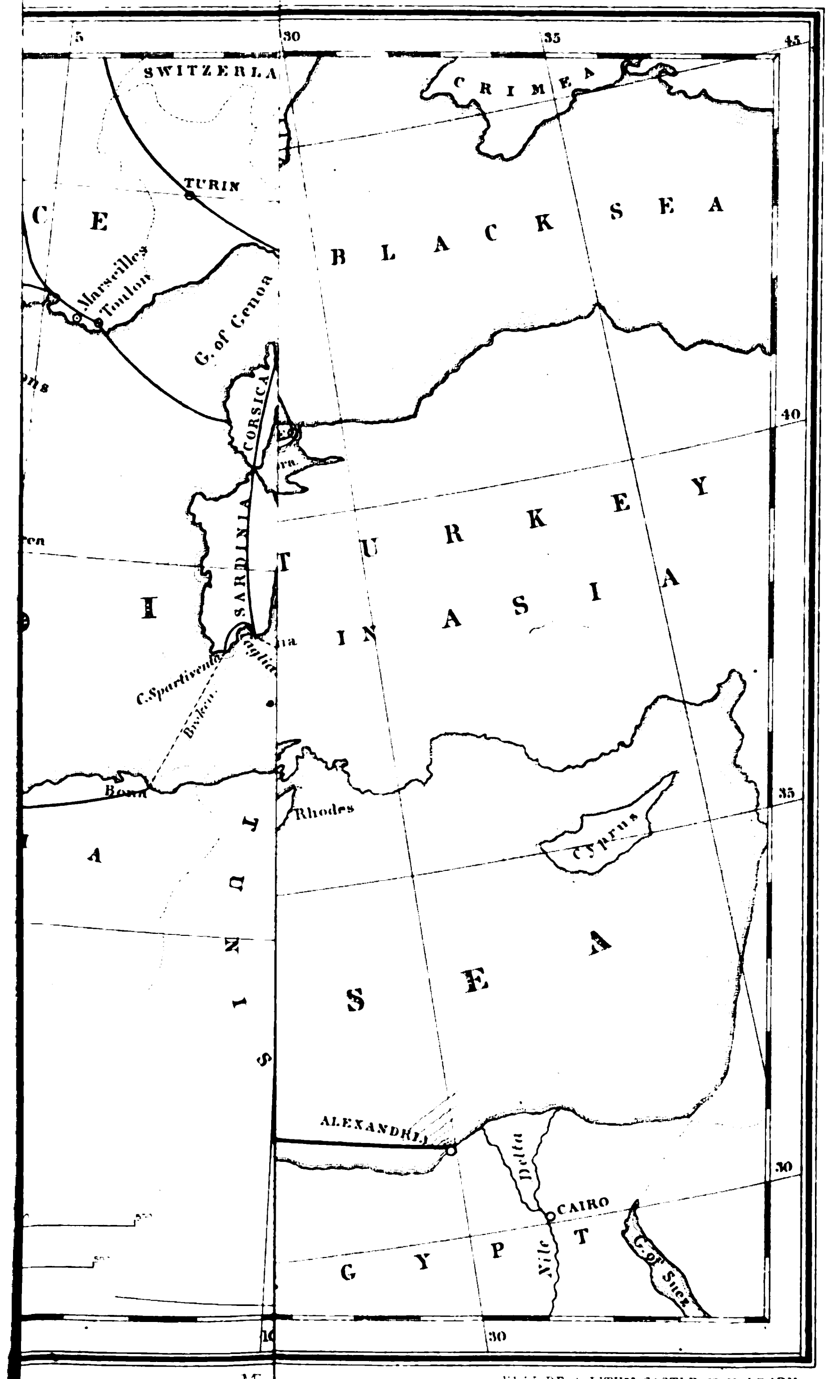
[1] On the Map (Plate 20) the telegraph to Constantinople should be in a direct line from Belgrade; and not, as represented, to Varna, and thence by a submarine telegraph to Constantinople.

PLATE 20. VOL. XXI.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CRIMEA
TURIN
CE
BLACK SEA
Marseilles
Toulon
G. of Genoa
CORSICA
SARDINIA
TURKEY
IN ASIA
C. Spartivento
Cagliari
Broken
Bona
Rhodes
Cyprus
SEA
ALEXANDRIA
Delta
CAIRO
Nile
GYPT
G. of Suez

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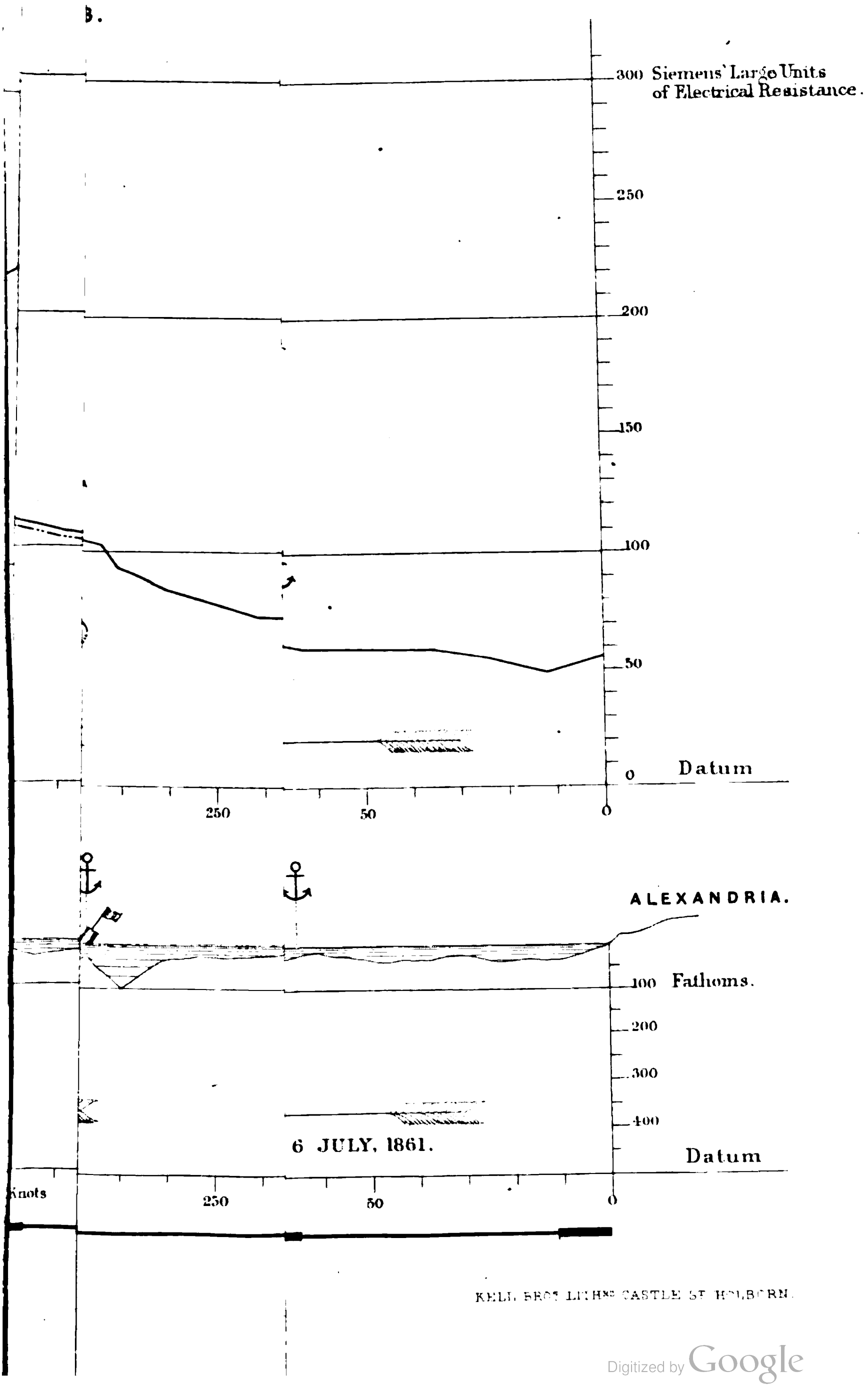
KELL BROS LITHRS CASTLE ST HOLBORN.



6 JULY, 1861.

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No. 1,072.—"On the Electrical Tests employed during the construction of the Malta and Alexandria Telegraph, and on Insulating and protecting Submarine Cables."[1] By CHARLES WILLIAM SIEMENS, M. Inst. C.E.

THE subject of submarine telegraphs having been fully discussed at this Institution during the last session,[2] the Author feels some hesitation in again introducing it. But several important circumstances have arisen since then, which render its further consideration desirable. The publication of the "Report of the Joint Committee on the Construction of Submarine Telegraph Cables" has disembarrassed the question of much uncertainty, by providing an impartial and complete record of the principal facts in connection with past experience. The experimental researches undertaken on behalf of that Committee have also added considerably to the stock of theoretical information, which was wanting to form a secure basis for further progress; and the successful completion of the Malta and Alexandria telegraph cable is another important fact, tending to inspire the public mind with fresh confidence in long lines of ocean telegraph. The Author having been employed by Her Majesty's Government, as the electrician to superintend the manufacture and shipment of this cable, can testify to its actual state of insulation, at the different stages of its progress, and to its general superiority as compared with former lines. The methods of testing employed differed essentially from those resorted to on former occasions; and although the system adopted was very much relaxed towards the conclusion of the work, it has contributed, nevertheless, to the establishment of a long submarine telegraph cable, far surpassing former attempts in apparent permanency and in transmitting power.

At the time the Atlantic Cable was manufactured, little was known of the requirements for such a line. The electric conductor was insufficient in size, and its insulation was so imperfect, even before it was shipped for its destination, that its momentary and partial success appears, at present, more surprising, than its subsequent entire failure. Since then, the Red Sea and India telegraph cable has been laid, in the years 1859 and 1860, without permanent success. The size of the conductor and the thickness of the insulating material were, in the latter case, well proportioned to the length of the intended sections of the line, which were not to exceed 600 miles. Some of the sections are asserted to remain in good working condition up to the present time, while others began to give way nine months after they were submerged, from causes which will partly be dealt with hereafter.

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[1] The discussion upon this and the preceding Paper occupied portions of two evenings, but an abstract of the whole is given consecutively.

[2] *Vide* Minutes of Proceedings, Inst. C.E., vol. xx., pp. 26-106.

The Author's connection with the Red Sea and India Telegraph was limited to the period of submerging the cable, when the firm with which he is connected undertook to superintend the electrical supervision and instrumentation of the line, on behalf of the contractors, Messrs. R. S. Newall and Co. Its insulation when laid, was superior to any previously manufactured, although it did not nearly approach the standard of comparative perfection, which has been reached with the same material, in the case of the Malta and Alexandria line. The latter may be said to be the first which was tested systematically during the progress of its manufacture and shipment; and had the same system of tests been continued during the outward voyage, and when submerging the cable, a valuable record might have been obtained, throwing additional light on the remarkable changes to which gutta percha is subject. Enough, however, can be shown to prove the importance of a uniform and well-devised system of electrical tests, to be carried on during the manufacture, shipment, laying, and subsequent working of submarine cables.

Electrical Tests.—The following system of tests was adopted in reference to the Malta and Alexandria (formerly the Falmouth and Gibraltar) cable:—The covered strand of conducting wire, in lengths of one nautical mile, was placed for 24 hours in tanks filled with water maintained at 75° Fahr. They were then removed into one of Reid's pressure tanks, containing water of the same degree of temperature. The coils of wire under operation, being by this time heated throughout to the above-named temperature, were tested both for conductivity and insulation; and the result expressed in units of resistance, noted down opposite the number of reference peculiar to each coil. A pressure of 600 lbs. per square inch was thereupon applied, and the same electrical tests were repeated. Before the coil under examination was approved, it was required that the copper resistance should not exceed 3·5 (Siemens') units of resistance, or possess 80 per cent. of the conductivity of chemically pure copper; and that the gutta percha resistance per knot, at 75° Fahr., should not exceed 90 millions of units, which also corresponds to about 80 per cent. of the highest insulation that can be attained with the best gutta percha of commerce. It was further required, that the insulation should improve when the pressure was applied, which is invariably the case if the coatings are sound. The approved coils of insulated conductor were transferred to the cable works at Greenwich, where they were kept submerged in tanks until the moment when they were required for the sheathing machine.

The sheathed cables were coiled into large tanks, where they were intended always to be covered with water; but, owing to some defect in the construction of the tanks, this regulation could only be partially carried into effect. It was also intended, in the first instance, that the ships should be provided with water-tight tanks, to receive the cable during the outward voyage; but owing to the passive resistance with which every deviation from previous routine is usually met, these tanks were not provided, until the heating of the cable on board the steam ship 'Queen Victoria' had proved, at great cost, that they were absolutely necessary. There are other important advantages obtained through the adoption of the water tanks: without them the electrical tests during the paying out are, to a great extent, illusory, partly on account of disturbances produced by irregular variations of temperature, and partly on account of the impossibility of detecting any fault in the insulating covering, unless the conductor and outer covering are brought into wet contact. If, therefore, faults of insulation occur on board ship, either through partial exposure of the cable to heat, or through an imperfect joint, or through accidental causes, they only make their appearance at the moment when the defective piece enters the sea, or sometimes even days after submersion has taken place. The sudden appearance of such faults has been hitherto of frequent occurrence, giving rise to interruption of the operation of paying out, and entailing great risk by kinks, or bad joints, or of losing the cable entirely when in deep water. In paying out the cable from a wet tank into the sea, these causes of failure are avoided, and the operation is rendered comparatively safe and easy.

In conducting the electrical tests of the Malta and Alexandria cable in the course of its manufacture, the Author made it his chief object to obtain throughout strictly comparative results. For this purpose, it was necessary to adopt a standard measure of resistance, by which to express both the conductivity of the copper conductor, and of the insulating covering. This standard measure has been supplied by the Author's brother and partner Dr. Werner Siemens. The unit of resistance according to this system is that of a column of pure mercury (contained in a glass tube), one metre in length between the contact cups, and of one square millimetre sectional area, taken at the temperature of melting ice. Of this unit, which can be readily reproduced with great accuracy, multiples are produced in the form of coils of German silver wire, covered with silk. A number of such coils, representing different values of resistance from 1 to 10,000, are fastened separately to a board of ebonite, the ends being soldered to contact pieces, by which means any number of the coils can be joined, so as to form one electric circuit of known total resistance, expressible in units. The testing apparatus is formed of three such scales of variable resistance, a battery, and a delicate sine galvanometer, or instead, where the space admits of it, a Weber's reflecting magnetometer. These are arranged together in the manner of a Wheatstone's bridge or balance, the cable to be measured forming the fourth resistance, or the unknown quantity in the equation, expressing the condition of a balance between the adjusted resistances. By an instrument of this construction electric resistances varying from the one hundredth part of a unit, to one million units, can be measured with great accuracy.

For resistances exceeding one million units, a different method was adopted, in which the resistance was calculated from the deflection of a very delicate sine galvanometer, acted upon by a battery of ascertained electro-motive force. The limits of this Paper will not admit of a detailed description of the testing apparatus which was used, or of the mathematical formulæ which were employed in reducing the observations into comparative numerical measurements.[1]

The diagrams in Plates 22 and 23 represent graphically the results of observations upon two different sections of the cable, taken at various stages of their progress: the one section being between Malta and Tripoli, and the other between Alexandria and Benghazi.[2] In Plate 23 are shown the tests applied to the parts constituting the Malta and Tripoli section of the cable, with the exception of a few knots, the presence of which has no perceptible influence upon the condition of the whole. In the diagrams marked A A, the insulation tests at the Gutta Percha Works are given. The length of the coils are taken as abscissæ, and the ordinates as resistances at 75° Fahr. The black line connects those taken in vacuo, and the broken line those taken under a pressure of 600 lbs. per square inch. The lower horizontal broken line represents the standard of 90 millions of units at 75° Fahr., to which it was found necessary to reduce the original standard of 100 millions, in consequence of the inability of the Gutta Percha Company to provide sufficient material of such high insulating qualities. The upper horizontal black line and the upper horizontal broken line, indicate the average derived from the observed resistances. Diagrams B B, Plate 23, give the curves of charge, discharge, and loss per minute, the ordinates of the latter curve, when the original charge is taken as unity, expressing in fractions the amount of current passed through the dielectric during the minute. The different diagrams, severally marked C and D, represent the results obtained at the Sheathing Works of Messrs. Glass, Elliot, and Co.; C represents the insulation, and D the charge, &c., as in the previous cases, but with the difference that there is no test under pressure, and that the abscissæ represent time. The diagram marked E shows the tests of insulation on board ship, and that marked F gives a comparison between the average resistances at 75° Fahr. observed at the Gutta Percha Works, after the sheathing, and finally on board ship shortly before submersion. The abscissæ represent in this case the length of cable. The diagram marked G gives the insulation actually observed during a certain period after submersion.

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[1] For further details on these subjects, see "Report of the Joint Committee on the Construction of Submarine Telegraph Cables," Appendices Nos. 7 and 12.—C. W. S.

[2] These observations are given in a series of Tables which are appended to the original communication, and may be consulted at the Institution.

The results obtained from the cables composing the section between Alexandria and Benghazi, are shown in a similar manner in Plate 22. The diagrams of insulation resistance in Plate 23, illustrate the state of a portion of this section (Cable, No. 5), which having been in a defective tank at the Sheathing Works, exposed to atmospheric influence, began to show symptoms of spontaneous heating. The insulation-tests fell low, while the resistance of the copper showed, by the ratio of its increase, that the mass of the cable must have attained a temperature of 80° Fahr. Upon this, the cable was cut into three pieces, which were marked 5 *a*, 5 *b*, and 5 *c*, and tested separately, when it appeared that 5 *a*, the portion which was at the bottom of the tanks had suffered most, while the two remaining portions still showed the marked effects of a gradual transition from a wet to a dry state.

The three portions of this cable, after being coiled over into another tank, and being kept under water, gradually returned to a normal state of tests, except 5 *a*, which never returned to its former high state of insulation, and which for some time gave rise to doubts, whether the effect of the heating had not rendered it unfit for use.

The ordinates in the diagram, connected by a black line, represent the resistances of insulation. The broken line shows the corresponding temperature in degrees Fahrenheit, calculated from the observed copper resistances; the abscissæ represent time. As might be expected from the limits between which the temperature varied, no material change was perceptible in the inductive capacity of the material.[1]

In order more effectually to guard against and to discover at an early stage, an undue accumulation of heat in any portion of the coil, the Government electricians placed between the coils, at regular intervals, certain instruments which may be termed resistance thermometers, based upon the principle, that the resistance of copper wire varies in a constant ratio with the temperature. The instrument consists of several layers of insulated wire of a known resistance, at the standard temperature, protected by an iron case, and brought into connection with the testing apparatus. By simply measuring the resistances of these coils, deposited at different places between the layers of the cable, any rise or fall of temperature throughout its mass is easily ascertained, by comparison of the resistance observed with the original standard. This system was found extremely useful, when applied, in observing the generation of heat in a portion of the Malta and Alexandria cable, then on board the 'Queen Victoria,' which had been kept dry during twelve days, and had attained a temperature of above 80° Fahr.; although the ordinary mercury thermometers, suspended in different parts of the hold of the ship, only indicated, during the same period, a maximum temperature of 60°. The diagram of copper resistances in Plate 23 exhibits the tests applied to the copper conductor in the Gutta Percha Works; the ordinates representing the resistances, in Siemens' units, per 1,000 yards, of the various coils contained in Cable 6. It will be seen, from this example, that the differences in the specific conductivity of the copper vary up to 16 per cent.

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[1] For further information on this subject, see the detailed reports by Dr. Allen Miller and Messrs. Siemens, Halske, and Co., upon the phenomena of the spontaneous generation of heat in this portion of the cable, which are given in Appendix No. 11 to the "Report of the Joint Committee on the Construction of Submarine Telegraphs."

Of the two sections under consideration, the Alexandria and Benghazi cable invites some further comment. It was laid at two different times. The tests of the first portion, though appearing rather low in insulation, proved otherwise regular, and tend rather to establish a general decrease of the insulating properties of the gutta percha, than to point to any local defect. In the second portion, however, a fault suddenly appeared, when the cable was coiled on board the 'Rangoon' in August 1861, indicated chiefly by a fluctuating resistance owing to electrolytic action. If several days could have been allowed to the Government electricians to observe and gradually develop this fault, it might have been cut out before the ship left the Thames; but such a delay was deemed unnecessary, inasmuch as the fault, if any, would certainly increase during the outward voyage, and the defective piece could be removed at Malta before the laying of the cable was commenced. On testing the same cable at Malta, it was found that its insulation had actually gone down from 120 millions of units to 3 millions of units; but it rose again to 70 millions of units after the faulty piece had been cut out. This piece has since been stripped of the iron sheathing, when a place about an inch in length appeared, where the gutta percha had been deeply indented, apparently by some weight falling upon it during the manufacture of the sheathing, which did not expose the copper conductor to sight, but which had assumed the character of a fault in coiling the cable from the tanks into the ship's hold.

On comparing the insulation of the cables after being laid down, with the insulation observed shortly before on board ship, there is a decided improvement after submersion. This is partly due to the pressure upon the cables, the insulation improving 2 per cent. on an average, per 100 lbs. of pressure upon the square inch, and partly to the lower temperature at the bottom of the sea. The latter circumstance influences the tests, by the introduction of a factor, the value of which it is difficult, if not impossible, to ascertain, owing to the changeable nature of gutta percha; thus preventing a direct comparison between the last tests on board ship and those after submersion. All that could be expected was, therefore, to find an adequate increase of insulation in testing the submerged cable, as compared with the last tests on shore; and that the electrification, both by positive and negative currents, should show the regularity due to a homogeneous condition of the insulating medium. Both these conditions were fulfilled in the case of the Malta and Alexandria cable.

Excepting in the one instance mentioned, no fault appeared in the cable after shipment, and having been laid very carefully, under the direction of Mr. H. C. Forde, the Government Engineer, there is every probability of its continuing for some years in good working condition.

The instruments for working the line were made by Messrs. Siemens, Halske, and Co., under the Author's general superintendence. They are ink-recording instruments, fitted with peculiar arrangements for discharging the residuary charge of the cable, and having the peculiarity of being capable of being worked by an exceedingly feeble battery power. One single Daniell's cell suffices for the transmission of messages through each section of the line, and when regularly working, not more than from eight to ten cells need ever be employed. Although the line is divided into three electrical circuits, messages are transmitted mechanically, and instantaneously, at the intermediate station, by a system of double relay, or translation, first introduced by Messrs. Siemens and Halske upon the continent. By this system of working, messages can now be sent instantaneously, from London to Omsk in Siberia, and there would be no electrical difficulty in establishing the same direct inter-communication between London and Calcutta. A detailed description of these instruments would fall beyond the limits assigned to the present Paper. The Author also passes over an important branch of the general subject, namely, the methods and apparatus employed for ascertaining the position of faults in submarine lines, referring those interested to the documents published in the Report of the Joint Committee on Submarine Telegraphs.[1]

The general superiority of the Malta and Alexandria cable over other long submarine lines, previously constructed, cannot admit of a doubt; and it is to be hoped that it may continue in good working condition, both on account of its national importance, and also for the sake of ensuring progress in this branch of engineering science. At the same time, it will hardly be asserted by the most ardent defender of the present form of submarine cable, that its construction is perfect, and should therefore be adhered to in the future. The difficulties encountered in the progress of this work are suggestive, both of the perishable nature of the outer sheathing, and of the tenderness of the insulating medium employed. Past experience has taught, at great cost, that the unprotected iron sheathing will be destroyed by rust, sometimes in the course of a year; that the hemp serving will be eaten by a marine insect[2] wherever it becomes exposed; and that the gutta percha is apt to develop faults, by slow degrees, wherever an irregularity in the insulating covering, although perfectly harmless at first, has escaped observation in the process of manufacture. Impressed with these views, the Author has for some years directed his attention to the construction of a cable of a more permanent character, and he is sanguine that his endeavours have led to some useful results, which he now proposes briefly to lay before the Members.

INSULATING MATERIALS.—Respecting the insulating covering, nature seems to have provided only two suitable substances combining permanent pliability, at all ordinary temperatures, with high insulating property, namely, india rubber and gutta percha. India rubber wrapped round the conductor in the form of strips, or bands, was first applied for insulating underground line-wires, by Jacobi, of St. Petersburg, about the year 1840. Gutta percha was applied for the same purpose, in 1847, by Dr. Werner Siemens, in Prussia, partly at the suggestion of the Author, the material being put upon the wire in a heated and plastic state, by means of a die. This latter process has since been exclusively adopted for insulating subterranean and submarine wires, until very lately when india rubber has been again put forward, in various forms, claiming a preference over gutta percha on account of its higher insulating power, its lower specific induction, and its power to resist higher temperatures.[3] On the other hand, gutta percha possesses the important advantage, that it admits of being put upon the wire in a plastic state, by means of a die, thereby producing a homogeneous covering, which may be applied in several layers, and which gives greater security against faults, than the lapped india rubber covering. It is, moreover, harder and stronger than india rubber at ordinary atmospheric temperatures, and therefore is less liable to receive accidental injuries. It is not liable to become sticky, or semi-fluid, when exposed to the atmosphere, and lastly, it resists the action of water more perfectly than india rubber.

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[1] *Vide* "Report of the Joint Committee on the Construction of Submarine Telegraph Cables," Appendix No. 12, &c.

[2] The Xilophaga, according to Huxley.

[3] *Vide* "Report of the Joint Committee on the Construction of Submarine Telegraph Cables," pp. xvii. and xxiii., and also Appendices No 1 and No. 2.

The absorption of water by insulating materials, including gutta percha, india rubber, and compounds of india rubber, such as vulcanized india rubber, Wray's mixture, and a compound with mica, under various pressures at different temperatures, and from water containing different degrees of salt in solution, is a subject which has been very fully investigated by Dr. Werner Siemens and the Author. The results of this inquiry, extending over three hundred days, are partly contained in Appendix No. 7 of the Report of the Joint Committee on Submarine Telegraph Cables, but have been much extended since the publication of that document. The results are graphically shown in a diagram in Plate 23. The ordinates in that diagram show the percentage of increase in weight of the materials examined at different periods after submersion: the abscissæ represent the time of immersion in days. The experiments were made on plates, as nearly equal in size as were procurable—1 millimetre thick, 100 millimetres long, and 50 millimetres broad, of the following materials, namely:—Raw india rubber, unvulcanized block india rubber, india rubber and mica, vulcanized india rubber, and gutta percha. The data given in relation to the latter material are taken from the results already published in the above Report. The specimens were immersed in a bath of distilled water, and in another bath containing 5 per cent. of sea salt, both vessels being kept at a temperature of from 60° Fahr. to 70° Fahr.

The following are the principal deductions to be derived from the experiments:—

1st. Increase of pressure up to the limit of 50 lbs. per square inch does not increase the rate of absorption in any of the materials operated upon. Absorption is favoured, however, to some extent, by a vacuum, owing probably to the absence of condensed air upon the surface of the material.

2nd. The absorption is more rapid from pure water, than from sea water; and more rapid from sea water, than from brine.

Notwithstanding the faculty of absorption of the gutta percha in both sea and pure water, and that of the remaining four materials in fresh water, had not quite attained the maximum after three hundred days' immersion, the relative absorptions of the several materials under examination may safely be assumed to be in the following proportions:—

	In Fresh Water. Per Cent.	In Salt Water. Per Cent.
Raw india rubber . .	25	3
Unvulcanized block do.	23	3·8
India rubber and mica .	19	3·9
Vulcanized india rubber	10·14	2·9
Gutta percha	1·5	1·0

India rubber in its raw and in its unvulcanized state is thus proved to absorb water in greater quantities than the other materials; while, next to gutta percha, vulcanized india rubber shows, both in fresh and salt water, the greatest insensibility to absorption.

3rd. In pure water the rate of absorption with increase of temperature is least influenced in regard to gutta percha, the rate being little more than double for an increase of 39° Fahr. to 120° Fahr. For india rubber the rate is about eight times, and for Wray's mixture about sixteen times greater at 120° Fahr. than at 39° Fahr., the latter being the temperature of water of the maximum density, as found at the bottom of deep oceans. In sea water, india rubber absorbs about double the quantity at 120° Fahr. that it does at 39° Fahr.; for gutta percha and Wray's mixture the rate of absorption is not materially altered by temperature.

4th. On removing the india rubber from the baths, previously to weighing, the surfaces were invariably found to be slimy, an observation which first led to the belief, that india rubber was soluble to a small extent in water. This fact is corroborated, and settled beyond doubt, by the curves of this material depressing towards the ends, as well as by the weights of the specimens, taken after the tests were concluded, showing a decrease from 0·4 per cent. to 1·2 per cent. It is also apparent, that the unvulcanized india rubber is likewise subject to solution in water, but in a less degree. The results of experiments, instituted with a view of ascertaining the dependence of absorption on the thickness of the material, only served to express a law, which might have been foreseen, that thicker plates absorb comparatively less than thinner ones. The difficulty of procuring materials physically equal leaves only a remote chance of arriving at satisfactory results in this respect.

The Author considers it important to notice some other experiments, at different temperatures, on the insulation and inductive capacities of wires coated with india rubber, and with gutta percha combined, as compared with those coated with gutta percha, or with pure india rubber alone. The lengths experimented upon varied from 600 yards to 2,500 yards, and consisted of—

1st. Wire covered by common gutta percha.
2nd. Ditto by two layers of special gutta percha alone.
3rd. Ditto by one coat of india rubber and two of gutta percha.
4th. Ditto by one coat of india rubber and one of gutta percha.
5th. Ditto by two coats of india rubber and one of gutta percha.
6th. Ditto by pure india rubber.

India rubber, both as the better insulator and the more absorbing material, should be applied nearest to the core.

The observations, ranging over temperatures between 50° Fahr. and 85° Fahr., are recorded in the columns of the following Table:—

TABLE I.

SPECIFIC RESISTANCE of GUTTA PERCHA and INDIA RUBBER, alone and combined, at Different Temperatures.

No.	Materials.	Radius.		$\frac{R}{r}$.	50° Fahr.			55° Fahr.		
		Outer R.	Inner r.		No. of Cells.	Defl.	Spec. Res.	No. of Cells.	Defl.	Spec. Res.
					a	*b*	*c*	*a*	*b*	*c*
1	Gutta percha	13	1	13	256	3·6	1·45	..	..	..
2	Special ditto	0·103	0·035	3·12	86	1·5	9·1	89	1·6	8·0
3	1 coat of india rubber and 2 coats of gutta percha	0·131	0·028	4·68	..	..	..	76	0·1	11·9
4	1 coat of india rubber and 1 coat of gutta percha	0·109	0·032	3·41	81	0·3	10·1	81	0·3	10·1
5	2 coats of india rubber and 1 coat of gutta percha	0·150	0·05	3·0	86	0·5	21·7	86	0·6	17·3
6	Pure india rubber . .	7·2	1	7·2	256	1·4	48·9	..	..	..

No.	Materials.	60° Fahr.			65° Fahr.			70° Fahr.		
		No. of Cells.	Defl.	Spec. Res.	No. of Cells.	Defl.	Spec. Res.	No. of Cells.	Defl.	Spec. Res.
		a	*b*	*c*	*a*	*b*	*c*	*a*	*b*	*c*
1	Gutta percha	..	..	..	..	..	..	64	12·5	0·64
2	Special ditto	89	3·0	4·2	91	4·1	3·2	89	3·8	2·5
3	1 coat of india rubber and 2 coats of gutta percha	71	0·1	11·3	71	0·2	5·6	71	0·3	3·8
4	1 coat of india rubber and 1 coat of gutta percha	81	0·3	10·1	73	0·2	6·4	73	0·3	4·3
5	2 coats of india rubber and 1 coat of gutta percha	89	0·9	11·5	91	1·2	8·8	88	1·4	7·5
6	Pure india rubber . .	..	..	..	..	..	..	512	4·4	41·3

No.	Materials.	75° Fahr.			80° Fahr.			85° Fahr.		
		No. of Cells.	Defl.	Spec. Res.	No. of Cells.	Defl.	Spec. Res.	No. of Cells.	Defl.	Spec. Res.
		a	b	c	a	b	c	a	b	c
1	Gutta percha	..	..	..	..	..	..	..	..	..
2	Special ditto	90	6·0	1·9	90	8·0	1·5	..	..	..
3	1 coat of india rubber and 2 coats of gutta percha	..	..	..	71	0·5	2·3	71	0·7	1·6
4	1 coat of india rubber and 1 coat of gutta percha	74	0·3	4·3	71	0·3	3·6	..	..	..
5	2 coats of india rubber and 1 coat of gutta percha	90	1·5	7·3	90	1·6	7·2	..	..	..
6	Pure india rubber . .	..	..	..	..	..	..	..	..	..

The subdivisions of the above columns contain, under *a*, the electromotive force employed; *b*, the observed deflection; and *c*, the specific resistance of the material.

Table II. shows the mean specific induction observed on these specimens, that of gutta percha being taken as unity.

TABLE II.

SPECIFIC INDUCTION of GUTTA PERCHA and INDIA RUBBER, alone and combined.

No.	Materials.	Radius. Outer R.	Radius. Inner r.	$\frac{R}{r}$.	No. of Cells.	Defl.	Spec. Ind.
1.	2.	3.	4.	5.	6.	7.	8.
1	Gutta percha	13	1	13	..	..	1
2	Special ditto	0·103	0·033	3·12	15	37.0	0·75
3	1 coat of india rubber and 2 coats of gutta percha . .	0·131	0·028	4·68	..	13·5	0·69
4	1 coat of india rubber and 1 coat of gutta percha . .	0·109	0·032	3·41	..	3·5	0·77
5	2 coats of india rubber and 1 coat of gutta percha . .	0·150	0·05	3·0	..	20·5	0·67
6	Pure india rubber . . .	7·2	1	7·2	5	12·8	0·66

In the above Table, columns 1 to 5 inclusive give the description of the cable tested; R is the outer radius and *r* the inner radius of the insulating covering; $\frac{R}{r}$ expresses the ratio; column 6, the tension; column 7, the deflection observed; and column 8, the specific induction. It will be observed that the fall of insulation, with the increase of temperature, is the more apparent and rapid, the greater the proportion of gutta percha in the combination.

Thus, the specific resistance of the special gutta percha decreases from 9·11 at 50° Fahr. to 1·50 at 80° Fahr., or to about one-sixth of its original value; while the combination of two coatings of india rubber and only one of gutta percha (No. 5), has, under the same circumstances, only gone down to about one-third of its insulation at 50° Fahr. On pure india rubber (No. 6) the effect of temperature is still less. It was also found, that the inductive capacity of the combined india rubber and gutta percha wire is not greater than that of pure india-rubber covered wire, that of gutta percha being equal to 1, that of the combination being about 0·7. It may further be remarked, that vulcanized india rubber, although some of its qualities are in favour of its application as an insulator for submarine cables, still cannot be recommended as being well suited for that purpose, both from its tendency to injure the conductor, by giving off a portion of its sulphur, and converting its surface into a sulphuret, and also from the danger arising from the amount of heat which it is necessary to employ during the manufacturing process.

On the other hand, notwithstanding the comparatively high insulating property of india rubber, its low inductive capacity, and its power to resist heat, its gradual dissolution in sea water is a circumstance which alone renders it inadmissible as an insulator of submarine telegraph wires, unless it is securely enclosed in another waterproof medium. Gutta percha appears in every respect well suited for such an outer covering, being itself sufficiently insulating to improve by its presence the insulation, and still more the loss by induction of the covered wire; applying itself closely to the india rubber; being susceptible of forming secure joints; and of resisting the sea water perfectly.

The mechanical problem of forming a sound india rubber and gutta percha covered wire, presented considerable difficulty. It appeared to the Author desirable that the india rubber should be brought upon the wire without the application of heat, or solvents, both of which often entail a gradual decomposition of that material; particularly when it is exposed to atmospheric influence, in contact with copper, or other metallic surfaces. Dr. Miller, in his Report to the Joint Committee on the Construction of Submarine Telegraph Cables,[1] states that the liquefaction of india rubber is the result of a process of oxidation; from which it may be inferred, that the effect cannot take place where oxygen is entirely excluded. It was important, moreover, that the india-rubber covered wire should be perfectly cylindrical, or it could not be covered properly with gutta percha in the die. Taking advantage of a peculiar property of india rubber cohering perfectly where two fresh cut surfaces are brought together, under considerable pressure, the Author has constructed a machine, by which any number of coverings of india rubber can be applied, in joining strips with longitudinal joints, tightly upon the wire, care being taken that the joints of consecutive coatings are at right angles to each other.

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[1] *Vide* Appendix No. 4 to the above Report.

Wires, and strands of wires, so covered with india rubber and gutta percha, with, and without intermediate layers of Chatterton's compound, have been under trial under various circumstances, exposed to the atmosphere, to water, or the moisture of the ground, for nearly two years, without betraying any signs of gradual deterioration of the india rubber, or the appearance of sudden faults. A circumstance greatly in favour of a wire covered in this manner is, that the gutta percha shrinks upon the india rubber, and when any mechanical injury to the covering occurs, the yielding india rubber is forced into the gap, by the elastic pressure exercised by the gutta percha, and thus prevents the formation of a fault.

The outer covering of cables, as hitherto constructed, is certainly the least perfect part. An iron sheathing is very necessary to protect the insulated core in shallow waters, where it is subject to tidal currents, and to the dragging of ships' anchors. The error which has been committed is, that wires of insufficient thickness have frequently been adopted. But, for deep-sea cables, that is, for cables in more than thirty fathoms, or, under special circumstances, forty fathoms of water, the iron sheathing is, the Author submits, an element rather of weakness than of strength, by rendering the cable ponderous, and its shipment expensive. The paying out is also rendered hazardous, partly on account of the heavy break-power required, and partly through the risk which would be occasioned, by the breaking of a wire between the ship's hold and the break-wheel. Repairs also, could not be conveniently made, and in some cases they would be impracticable, owing to the difficulty of safely raising a heavy cable from a great depth, under any circumstances, and the impossibility of doing so after corrosion of the iron wire has made any progress. When the Falmouth and Gibraltar cable was first contemplated, the Author, in conjunction with Mr. Forde, proposed that each iron wire should be covered with gutta percha, with a view to prevent oxidation; but the system was not acted upon, except experimentally.[1]

Mere protection of the iron wire is, however, not sufficient, in the Author's opinion, to constitute a good deep-sea cable. It is capable of mathematical demonstration, that in paying out a wire-sheathed cable, with a considerable strain upon the break-wheel, it will untwist, while in suspension in the water, to a considerable extent, causing elongation of the core to the amount of say one per cent., or even more. On reaching the bottom, the strain and consequent twist will be released, and throw the cable into frequent kinks. But it appears, from experiments made at Camden Town by the Joint Committee on the Construction of Submarine Telegraph Cables (Appendix No. 9 of their Report), that copper wire cannot be elongated more than 2 per cent. without receiving a permanent set. It is also a well-ascertained fact, that when telegraph core has been stretched at any time beyond the limits of elasticity of the copper, the latter being henceforth too long for the more elastic covering, will tend to assume a serpentine form, and will push its way through the insulating material by slow degrees, particularly in places where short bends, or kinks occur.

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[1] The results of the experiments referred to are given in the Report of the Joint Committee on the Construction of Submarine Telegraph Cables, Appendix No. 10.

Based upon these views, the Author designed a sheathing of the following description:—The conducting strand of copper wires consists of seven comparatively strong and six thinner wires, which latter fall into the spiral grooves between the former, and produce a near approach to the cylindrical form, presenting the least surface, for a given conducting area. The small remaining interstices are filled up with Chatterton's, or some other compound before the conductor is covered, first with pure india rubber, in two layers, by the process before described.' The india rubber covered conductor is carefully tested, and thereupon covered with gutta percha by the ordinary die; Chatterton's compound being used to solder the two materials. The insulated conductor, or core, thus formed, is passed in the sheathing works through a series of three machines in close succession. In passing through the hollow spindle of the first machine, a close spiral covering of hemp, previously saturated with Stockholm tar, is applied, in such a way that each string is, and remains, under a given strain, which may be adjusted by friction-breaks. The second machine is similar in construction to the first, but it supplies a second covering of hemp, wound in the opposite direction to the first. The rope thus formed passes next through a stationary clip, with longitudinal grooves, to prevent it from turning round, in the operation immediately following. This consists in the application, under the influence of great pressure, of from three to six strips of copper, or other metal, which may best resist the action of sea-water. The strips are coiled upon reels, and are accurately guided into the revolving covering tool, so as to overlap each other equally for nearly half their breadth; the pressure applied being sufficient to crush, or socket the one metal down where it is covered by the other. The cable thus formed passes over a capstan-wheel, by which it is drawn through the three machines, notwithstanding the retarding form applied to the numerous hemp strings constituting the strength of the cable. In passing away from the capstan-wheel, the extended hemp strings would naturally shorten to their original length; but are prevented by the tight grasp of the metal sheathing. For the same reason they are not at liberty to shrink, when the cable is immersed in water.

This cable has no tendency to untwist. Its extension, with half the breaking strain upon it, does not exceed 0·3 per cent., and being very strong, and of only double the weight of water, it will support from 7 miles to 8 miles of its own weight in the sea.

Considering that good ship's sheathing lasts from ten years to twelve years, when the ship is at rest, and that this cable has a double layer of metal, with hardened tar between the layers, it appears not unreasonable to suppose that the sheathing will last, at the tranquil bottom of the ocean, not less than from twenty years to thirty years. Several short lengths of this cable are now being tried, under various circumstances, and the results, so far as they go, promise to be very successful upon a larger scale.

In conclusion, the Author wishes to acknowledge the valuable assistance he has received, in preparing the statistical portion of this Paper, from Messrs. Loeffler and Deede, electricians in the employ of Messrs. Siemens, Halske, and Co.

The Paper is illustrated by a series of diagrams, from which Plates 22 and 23 have been compiled.

[Mr. HAWKSHAW,—

PLATE 22. VOL: XXI.

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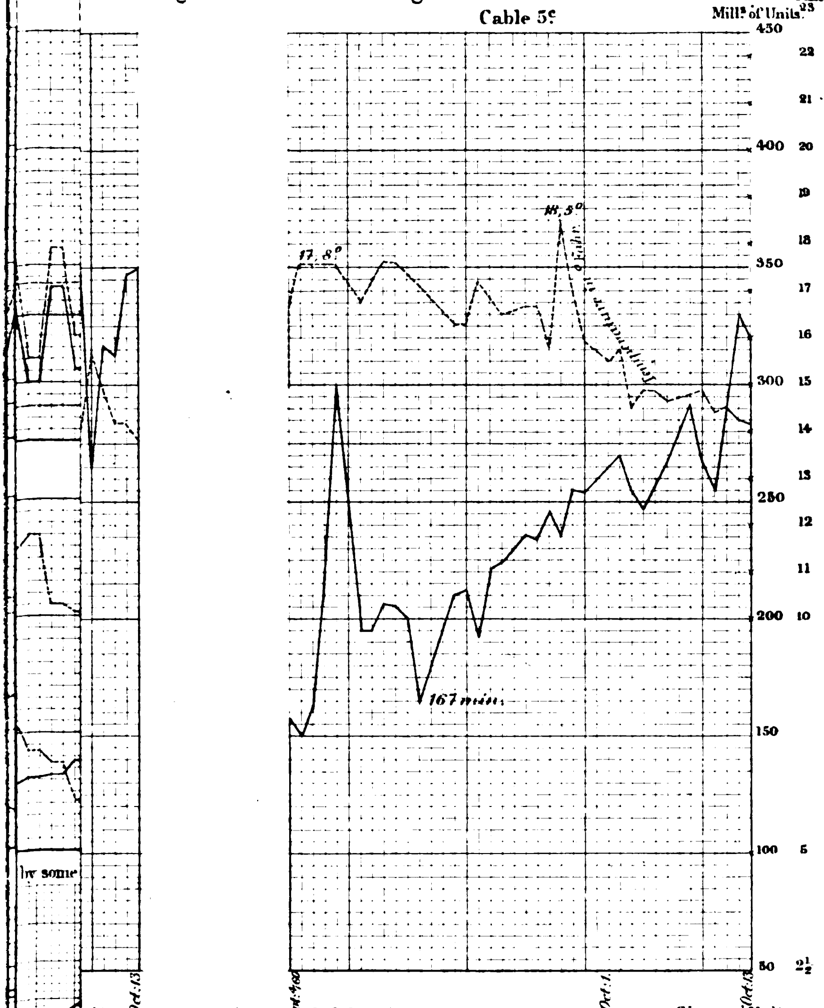
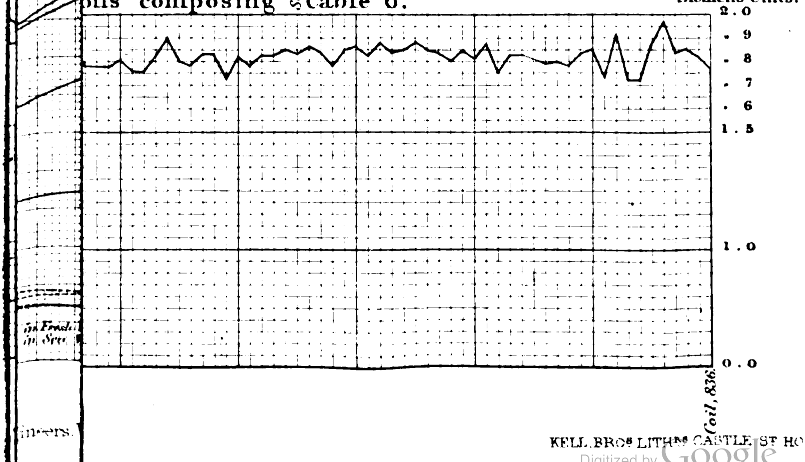
TION. 5º during and after selfheating.



oils composing Cable 6.



KELL. BROS LITHRS CASTLE ST HOLBORN.

Mr. **Hawkshaw**,—President,—said, that as the Papers which had just been read, would be peculiarly valuable for reference, it would be very desirable that they should be printed in the current volume of the Minutes. As it was the last meeting of the Session, he would suggest, that the discussion should not be adjourned, but, that the remarks made, should be as brief as possible.

Sir **Charles Bright** stated, that when called upon in May 1859 to advise the Government as to the Malta and Alexandria cable, then proposed to be laid between Falmouth and Gibraltar, he recommended that the conducting wire should be formed of copper strand of the weight of about $3\frac{1}{2}$ cwts., or 392 lbs. per knot, covered with three separate coatings of gutta percha, and three of Chatterton's compound. The total diameter of the core was to be half an inch. His advice was practically acted upon, the Gutta Percha Company being ordered to construct a cable with a copper strand of about 400 lbs. per knot as the conductor, and a dielectric of the diameter of half an inch. When he recommended the above described core to the Government he stated, that a telegraphic speed of ten words per minute could be obtained by means of it through the then proposed circuit of eleven hundred knots. That statement was the result of careful experiment, and previous experience through circuits of the same length. The late Mr. Robert Stephenson also, who as Chairman of the Electric Telegraph Company had every facility for obtaining correct data, expressed a similar opinion. It appeared that the speed then estimated had not been obtained on the greater length of thirteen hundred and thirty knots between Malta and Alexandria, but it should not thence be inferred that too sanguine expectations had originally been formed of the capacity of the core which was actually in use. He was still of opinion that with instruments properly adapted to the requirements of the line, under the charge of competent people previously experienced in working long circuits, a speed of ten words per minute could be obtained through eleven hundred knots of the cable. Such an experiment could be readily tried upon the section between Tripoli and Alexandria, which was within a few miles of that length. As far back as 1856 he advised the promoters of the Atlantic Telegraph Company to construct the Atlantic Telegraph with a core of precisely the same diameter, but owing to financial and other considerations, his recommendation was not carried into execution. If his proposal had been adopted, the Atlantic Telegraph cable would have had six times the amount of insulating material which had been used in any previous telegraph cable, and in his opinion the difficulties subsequently experienced in the electrical department of the Company's operations, and which had caused the breaking down of that line, would have been avoided, and the telegraph would probably have been still at work between Valentia and Newfoundland, at a much higher speed than had been obtained during the three, or four weeks, when the electricians had successfully worked it. The recommendation which he had given so shortly afterwards, in the case of the proposed Falmouth and Gibraltar cable, to use a core of the same diameter for a circuit of only half the length of the direct Atlantic line, was an illustration of the extent to which he considered experience had confirmed the correctness of his previous views. Had he now to give a design for a new telegraph line between Ireland and Newfoundland, he should recommend that both the dimensions of the insulating material and its cost should be greatly increased. An attempt had been recently made to revive that project, and a core of 510 lbs. of copper per knot and 550 lbs. of gutta percha per knot had been proposed, and exhibited at the meetings of the company and elsewhere, as the core which would probably be adopted. In reference to that core, Mr. Forde in a published letter to Mr. Cyrus Field of the 15th March, 1862, had stated his opinion, that a telegraphic speed of eight words per minute could be obtained through the proposed circuit, which was 2,000 knots in length, if Professor Thomson's, and Mr. Fleeming Jenkin's instruments were used. According to that estimate, a line one-third longer than the Malta and Alexandria Line could be worked at twice the speed of the latter, by adding 150 lbs. per knot to the gutta percha covering, and 110 lbs. of copper to the conductor, and by using special instruments. When Mr. Robert Stephenson and himself estimated, that the telegraphic speed of the proposed Falmouth and Gibraltar cable would be ten words per minute, through a circuit of eleven hundred knots, they did not, of course, expect that such a circuit would be worked with the ordinary instruments used for short lines, but on the contrary they contemplated the use of apparatus familiar to those who had devoted their attention to the requirements of long lines, and by means of which that rate of telegraphic speed had been attained, under circumstances which afforded reliable data for the calculation. It would, however, be unnecessary to extend his remarks on this branch of the subject, as the rates of speed which had been given in the first Paper could not be considered as conclusive, being only given "as the nearest approximation which could be arrived at after a few days' trial."[1]

In reference to the outer covering of the Malta and Alexandria cable, it was much to be regretted, that it had been adopted without regard to the bottom on which it had been laid. In his own report he had only in view the deep sea route between Falmouth and Gibraltar. When the destination of the cable was changed, previously to taking the proper soundings along the proposed route, a design for an outer covering was selected from the pattern of a very defective line, and hence, instead of a strong and massive cable, such as had been permanently successful elsewhere, in shoal water, a comparatively slender cable had been used, the outer covering of which it was to be apprehended would soon be destroyed by rust. Had a strong cable been adopted, and had the advice given by Mr. Stephenson been taken, of covering the wires with a protecting coating of bitumen and fibrous material, it would have lasted for a long term of years, and all the series of misfortunes which had been encountered, owing to the rusting of the cable, even while it was yet in the tanks, would have been avoided. Other cables had been covered in the manner recommended by Mr. Stephenson, and no difficulties had been experienced in the mode adopted, of applying the compound used, either in testing, or as regarded the heating of the core. Difficulties of that character need not be apprehended, where ordinary care was used in the manufacture of the cable. The depths were given as only 47 fathoms between Benghazi and Alexandria, and 70 fathoms between Benghazi and Tripoli; while the bottom was described as irregular, hard, and rocky. He feared that if the cable had to be repaired at the expiration of four, or five years, there would be great difficulty in lifting it over the bows of a ship. The cost of laying a substantial line well protected from rust would of course have been greater, but it would have been the cheapest plan in the end. It had been stated in the first Paper, that the outer covering of iron wires was much larger than those of the Atlantic, the Red Sea, and either of the Mediterranean lines which had been fatally injured by corrosion; it must, however, be remembered, that the Atlantic was almost entirely a deep-sea line, and the short portions of it which were laid in shallow water near the shores were of very large dimensions. The Red Sea cable had rusted rapidly, and extensively, as would be seen by a specimen which he exhibited. The cable which he had previously mentioned, as being that from which the outside covering of the Malta and Alexandria cable had been apparently copied, was the cable which had been laid in 1857 from Sardinia to Cape Bona. That cable had four inner, or conducting wires, but in every other particular the two cables were so much alike outside, that they could not be distinguished when apart, except by stripping off the outer covering, and examining the inside. During the discussion of the Paper on Submarine Telegraphs, by Mr. William Henry Preece, (Assoc. Inst. C.E.,) Mr. Fleeming Jenkin, who had recently returned from attempting to repair the cable between Sardinia and Cape Bona, described it as being so corroded by rust that it was practically impossible to lift it, and that after it had broken repeatedly, it was obliged to be abandoned altogether.[1]

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[1] *Vide* ante page 512.

It was therefore seriously to be apprehended that at the expiration of three years, or four years, it would be necessary, at great cost, to replace the Malta and Alexandria cable, in different parts, by lengths of a heavier cable. In the course of the discussion he had just referred to, he had, in answer to a question from Mr. Bidder (then President, Inst. C.E.), expressed an opinion, that the cable was not sufficiently strong to be laid down in the shallow water, where it was proposed to lay it, and that it should have been well protected from oxidation.[2] He feared, that the disregard of these necessary conditions would be the cause of future disasters, by which the extension of submarine telegraphs would unjustly suffer, in the minds of those who could not be expected to search into their origin.

The laying of the Malta and Alexandria cable was undoubtedly a very successful mechanical operation, and was one which reflected great credit upon Messrs. Canning and Clifford, the Engineers to Messrs. Glass, Elliot, and Co. It was owing to their skill and care, and to the pains with which Captain Spratt had taken the soundings, that it was probably the best laid cable in existence. Referring to the experiments brought before the Institution by Mr. Siemens, Sir Charles Bright remarked, that gutta percha had by itself been every way successful in moderate temperatures, and in the cases of cables which had been down for many years it had suffered no change. It, however, required great care in a high temperature. The experiments which had been made with respect to the use of india rubber as an insulator were of great importance, and he trusted that, by improvements in its manufacture, an insulating covering would be discovered, which would stand the change of temperature better than any at present in use; and on this point he would add, that sulphurized, or vulcanized india rubber appeared to offer a most promising field for experiment.

Captain SELWYN, R.N., said, that the duration of copper under water had been accurately determined. In the Royal Navy sheathing copper was classified into three years' copper, five years' copper, and seven years' copper. The three years' copper was only the thirty-second of an inch thick. When protected from corrosion by the process of Sir Humphry Davy, it failed entirely to fulfil the purpose for which it was put upon the bottom of a ship, namely, that of preventing the adhesion of barnacles and other objectionable sea deposits. Moreover, the small pieces of iron which were used in that process became decayed by galvanic action, the copper remaining unchanged; or, in other words, the copper was protected at the expense of the iron. He believed, that neither copper, brass, nor any other material would remain unimpaired sufficiently long to repay the cost of its use in sheathing telegraph cables. As a nautical man he had directed his attention to the question of the best mode of stowing, and paying out, telegraph cables, and he had arrived at the conclusion, that the only way of avoiding the difficulties and hazard of the present mode of coiling away cables, and of paying them out, was to coil them on a large detached floating reel, or cylinder, fitted with paddles, so that the cable could be paid out by towing the cylinder astern of the vessel.

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[1] *Vide* Minutes of Proceedings, Inst. C.E., vol. xx., p. 81.
[2] Ibid., p. 72.

Professor W. THOMSON considered, that with a cable of eleven hundred knots, having the same sectional area and dimensions as the Malta and Alexandria cable, a telegraphic speed of ten words per minute ought to be obtained. That estimate was based upon actual experience of the working of the Atlantic Telegraph. Morse's alphabet had been used, and a telegraphic speed of two and a half words per minute, fully spelt and without abbreviations, was attained. According to a well-established law, the speed of working through half the Atlantic cable would have been four times the speed actually attained through the whole length. From the preceding data he had no doubt that in the case of the thirteen hundred knots, which formed the entire length of the Malta and Alexandria cable, a speed of twelve fully-spelt words per minute might be obtained with instruments adapted not only for high speed, but also for convenience and certainty. With reference to the battery power which would be required, he believed, that the smallest battery power was sufficient to produce the speed he had mentioned, and that ten cells would be quite sufficient.

The theoretical result from the law of the squares, using the data derived from the working of the Atlantic Telegraph cable, and taking into account the greater lateral dimensions of the Malta and Alexandria line, would considerably exceed twelve words per minute.[1]

It was to be hoped, that the forebodings which had been expressed, as regarded the permanency of the cable might not be realized, and either that repairs might not be required, or that if required they might be successfully executed. It would, however, be extremely unwise to lose sight of any such possible contingency, and in designing future submarine telegraph cables, every effort should be made to insure the permanent protection of the insulating medium. From the rapid advance of telegraphic science and experience, he hoped that this important and difficult problem would be solved, and that a submarine telegraph cable would be designed, constructed, and laid, with the same prospect of success and permanency as a bridge, or a railway.

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[1] This calculation has since been made, and the result gives fifteen and a half words per minute for 1,330 knots of cable.—W. T.

Mr. JOHN CHATTERTON stated, that the Gutta Percha Company had contracted with Her Majesty's Government, to supply the core for a cable to be laid between Falmouth and Gibraltar, but which was eventually laid between Malta and Alexandria. Nearly 700 knots of this core had been manufactured before the Government electricians were appointed, and had been immersed a considerable time before Mr. Siemens commenced the testing. To meet the arrangements of Her Majesty's Government, the manufacture of the core was suspended, and when it was resumed, the newly-made core was submitted to the tests, and would not of course give the same electrical resistance as that which had been manufactured in the earlier stages of the contract, and had been immersed for a longer period. It was on this account that Mr. Gisborne offered to reduce the standard from 100,000,000 units to 90,000,000 units, and not owing to any inferiority in the gutta percha which had been used in the manufacture of the core.

Mr. JOHN MACINTOSH could not concur in the statement, that the relative absorption of water by india rubber was 25 per cent., as compared with the small amount of 1·5 per cent. in the case of gutta percha. He had made experiments as to the solubility of india rubber in water, and he found, that it was impossible to dissolve it. No doubt it would absorb a certain amount of water, and gutta percha would do the same. The absorption of water was a serious question as regarded the durability of submarine telegraph cables. In the small sections of the Atlantic Telegraph cable made for ornamental purposes, it had been found that in a few years the gutta percha had shrunk at both ends. He had specimens of the cores of telegraph cables, in which the gutta percha had receded from the telegraph wires to the extent of the eighth of an inch. A piece of gutta percha, newly manufactured, would weigh more than after it had been exposed to the air. He attributed that to the water which it contained, according to the law of endosmose and exosmose. The greatest care should therefore be taken to keep the gutta percha and the india rubber dry. One question to be determined was, whether the conductor should be covered with the gutta percha in a hydrous, or in an anhydrous state, and whether a hydrous core could be as easily worked through as an anhydrous core. It was quite certain that india rubber would absorb water to a considerable extent. Dishonest dealers in that article soaked it to increase its weight before bringing it into the market. He considered that gutta percha, or india rubber should be put on the wires in an anhydrous state. In making long lengths of submarine cables, he had adopted the practice of putting those gums on the conductor in as pure a condition as possible. When they were solidified, he covered the core with a preparation of copal and collodium, which made a coating as impervious to water as glass. There was no mechanical difficulty in the manufacture and laying of telegraph cables, but it was a serious matter for consideration, how long they would remain commercially useful, unless they were coated by an impervious covering. The Malta and Alexandria cable possessed the same features as the Atlantic cable, with the exceptions, that it had a larger conductor, that the lengths worked through were shorter, and that it had received several coats of Chatterton's compound. From an analysis which he had made of that compound, he found that it consisted principally of Stockholm tar and resin. In reference to this combination, he would draw attention to the fact, that neither india rubber nor gutta percha were palatable to marine insects, but when those substances were mixed with Stockholm tar, they were extremely so.

Mr. H. C. Forde in reply said, when he had given his opinion, three years ago, as to the rate of speed which would be attained by means of the Malta and Alexandria cable, that opinion was based upon the assumption, that the instruments adopted would be such as were then in ordinary use. Since that time great improvements had been made in telegraphic instruments. Some of the instruments which were now known would, if used, treble the rate of speed through the cable. Consequently, the telegraphic speed of three and a half words per minute given in Table V. as that which had been attained through the whole length of cable, might, by an improved system of working, be increased to nine, or perhaps twelve words per minute. He, however, believed that the instruments which had been made by Messrs. Siemens and Co., and which were at present in use on the Malta and Alexandria line, were on the whole the best for ordinary use on submarine circuits. With these instruments the greatest telegraphic speed which could be attained through the whole length of cable would be four words per minute. That would be at the rate of five words per minute through 1,100 knots, which was the original estimate he had given to the Government.

The outer covering of the Malta and Alexandria cable was, as stated in the Paper, much larger than the other Mediterranean cables containing a single conductor.[1] The telegraphic cable between Sardinia and Cape Bona, which had been referred to, contained four conducting wires, but it was covered with the same size of iron as that which had been used for the Malta and Alexandria cable. At the time that cable was laid, it was considered a heavy cable. It should also be remembered that a much heavier cable had been laid in all the rugged and uneven parts of the Malta and Alexandria line. In the third section shown in Fig. 3, Plate 21, as much as 133 knots of cable, weighing about seven tons to the knot, were laid in different parts, one length alone being 70 knots. But in laying long lines of submarine telegraphs, it was impossible to lay such heavy cables as could be laid on short lines, such for instance as those between this country and France. The increased expense alone presented a formidable obstacle. No doubt it would have been preferable, that the Malta and Alexandria cable should have had an outer covering to protect the wires from rust. He must, however, reiterate that it was not originally designed for a shallow-water line, and that if its original destination had been adhered to, the shallow water was to have been passed over with cable weighing seven tons per knot, and five tons per knot. Sir Charles Bright, in his Report to Sir Stafford Northcote, did not recommend that the iron should be covered to prevent corrosion. The only means then known of effecting that object was the process of Mr. Latimer Clark, but that method of covering submarine cables was considered dangerous, as the material had to be applied at a very high temperature, and injuries to the core might have ensued, and remained undiscovered until after the cable was laid. Moreover, when the destination of the cable was changed to a shallow-water route, the question of protecting the iron covering was laid before the Government. As the cost of the covering proposed amounted to £65,000, the Treasury did not feel justified in incurring that additional expense, and nothing further was done in the matter. Every precaution was, however, taken to select a level and uniform route. The line did not cross any locality where vessels usually anchored. So that looking to all the circumstances of the case he trusted, that the cable would remain a long time in working order, and that, should repairs become necessary, they would be easily executed in the small depth of water in which the cable had been advisedly laid.

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[1] *Vide* ante page 497.

Mr. C. W. SIEMENS, after exhibiting the instruments used in testing the cable, which had been described in his Paper, said, that no doubt a much higher rate of working through the Malta and Alexandria line could have been obtained, if the object had simply been to transmit the greatest number of words per minute, irrespective of other considerations; but the principal object had been to produce a safe instrument, which, in the hands of an ordinary working clerk, would transmit without failure the greatest number of messages, with the least amount of battery power. The high temperature of the Mediterranean near the African coast, also rendered the use of a very low battery power a matter of great practical importance. The term 'working speed' was often understood in a different manner from that in which he regarded it. He considered it to mean the speed obtained when working ordinarily, and fully spelling all the words with the recording instrument. By using abbreviations, and by dispensing with translations at intermediate stations, the speed might be increased. Since the Malta and Alexandria cable had been laid, further improvements in telegraphic instruments had been made by the firm to which he belonged, by means of which the required conditions were fulfilled, and a higher rate of working was attained.

As regarded the Gutta Percha Company, he wished it to be distinctly understood, that it was not in disparagement of their work that he had stated in the Paper, that it was found necessary to reduce the standard from 100 millions of units to 90 millions of units. On the contrary, he thought the Company had made extraordinary progress in the manufacture of gutta percha during the last few years. In fact, the gutta percha in the core of the Malta and Alexandria cable, taken specifically, insulated, material for material, several times better than that in any other cable previously manufactured; but, to give a faithful record of what had happened, it was incumbent upon him to mention the fact that the standard had been lowered. It had been stated that neither gutta percha, nor india rubber were soluble in water, and that they were capable of being made insoluble by covering them with a preparation of copal and collodium. He would refer to the diagram, Plate 23, showing the results of experiments extending over an interval of 300 days; and from that it would be seen, that in sea water, india rubber, and especially bottle india rubber, lost considerably in weight after 100 days' immersion. At first a slimy skin formed upon the surface, which by degrees increased, and, although the quantity of india rubber actually dissolved was small, yet that fact of its dissolution had to be borne in mind in the construction of submarine telegraph cables. However slow the action might be, it would ultimately prove destructive to the cable, as the places which would suffer most would be those where the insulation was already feeble from injury, or from partial defect in the coating. Before venturing to propose the outer covering of copper referred to in the Paper, he had collected all the data upon the subject which he could obtain. The motion of a vessel had the effect of washing off the chloride of copper and magnesia which formed upon the metal. So that although copper sheathing on ships which were kept in motion did not last longer than from 5 years to 7 years, yet in the case of vessels at rest, copper sheathing had been known to last as long as 20 years. In the case of a cable lying tranquilly at the bottom of the ocean, still greater durability might be calculated upon. The copper ordinarily used for ships' sheathing was by no means the most durable that could be obtained. Dr. Percy had found that a small proportion of phosphorus put into the copper had the effect of making it less soluble in sea water than pure copper, and that result was corroborated by his own experiments. Mr. Siemens proposed to use a compound of that character. Small admixtures of silver, or tin appeared to have the same effect, and it was possible that an alloy of that character might be applied, with equal, or greater advantage.

Mr. HAWKSHAW,—President,—said, that he considered Mr. Siemens was proceeding in the right direction in the improvements which he was effecting. As regarded the durability of copper in sea water, the friction of a vessel passing through the water should be taken into account, when estimating the wear of the copper sheathing. It could not be expected, that metal in motion would last as long as that which remained in a quiescent state at the bottom of the sea. With reference to the alleged great expense of making submarine telegraph cables of a durable character, he certainly did not see how success could be expected, unless that expense was incurred. It was idle to suppose that a light cable with a small section could be durable. The failure of the Atlantic cable might be taken as a case in point. The Papers which had been read were as valuable as they were interesting. The first Paper afforded a detailed description of the successful performance of a difficult mechanical operation, and the second Paper contributed the scientific results derived from a series of testing operations, which had been conducted with great care and minuteness. No doubt the precautions which had been taken in laying the cable, and the careful system of testing which had been adopted, had been the means of securing the successful completion of the Malta and Alexandria line.

IMPROVED SEXTANT.

After the Meeting, Mr. F. C. Webb (Assoc. Inst. C.E.) explained a modification of the ordinary sextant, by which larger angles could be measured than with the instruments now in use. Two sextants (made by Messrs. Fletcher, of Leadenhall Street,) were exhibited, one on the common arrangement and the other on the modified principle.

It was stated, that when the arm of the common sextant was at zero, the lines of incidence and of reflection, of an object seen in the horizon glass, formed a certain angle with one another, both at the object and horizon glass; and that this angle, termed the constant angle, deducted from 180°, gave the extreme theoretical angle which could be measured Practically this measurement was still further reduced by the limits within which it was possible to reflect an object from a plane surface with accuracy, and which, if assumed as 170° instead of 180°, would give the angle from which the constant angle must be deducted to obtain the extreme angle capable of being measured. The smaller the constant, therefore, the nearer would this angle approach 170°, with a given amount of accuracy. It was observed that this constant angle was dependent on the relative position of the object glass, the eye piece, and the horizon glass, and was, in fact, the angle formed by a line drawn from the eye piece to the centre of the horizon glass, with a line drawn from the centre of the horizon glass to the centre of the object glass.

The reduction of this constant angle to a minimum was effected in the modification alluded to, by placing the eye piece very near to the object glass, and the horizon glass as far as possible both from the object glass and the eye piece. The extreme angle capable of being measured was thus considerably increased, and with conditions more favourable to accuracy; for whilst the angles of incidence and reflection in the object glass were not smaller than in an ordinary sextant, those in the horizon glass were constantly larger. With a given angle to be measured the conditions were more favourable to accuracy, since the lines of incidence and reflection formed larger angles with the reflecting surfaces both in the object and the horizon glasses.

In marine and land surveying, and in taking altitudes of celestial objects with an artificial horizon, (where the angle to be measured was double the altitude,) this increase in the capabilities of the instrument was, it was believed, a manifest advantage.

May 27, 1862.

The Session was concluded by a CONVERSAZIONE, at which the President received the Members of the Institution, and a numerous circle of distinguished visitors. The rooms were decorated with many choice works of art, and there was also exhibited a large and interesting collection of mechanical models.

APPENDIX TO VOL. XXI.

MEMOIRS.

Mr. EATON HODGKINSON was born on the 26th of February, 1789, at Anderton, in the parish of Great Budworth, near Northwich, Cheshire, at which place his father was engaged in farming pursuits. On the death of his father, which occurred when the boy was only six years old, he was, at the instigation of his uncle,—the Rev. Henry Hodgkinson, rector of Arberfield, Berkshire,—placed at a classical school, with the view of his proceeding to the University, and of ultimately entering the Church. In the study of the Classics he does not appear to have made any progress, and he was soon transferred to the care of Mr. Shaw, at that time the master of the grammar-school at Northwich, under whom he laid the foundation for his future mathematical acquirements, and to whose careful tuition Mr. Hodgkinson frequently alluded in after-years.

The pecuniary circumstances of Mrs. Hodgkinson induced her to remove, in the year 1811, to Salford, Manchester, where she entered into business, and, with the assistance of her son, eventually attained a comfortable position. He was not, however, intended by nature to emulate the thrifty and active examples around him in that city of millionaires; his tastes led him rather to listen to the mathematical teaching of Dr. Dalton, one of whose most distinguished pupils he became, and with whom he formed a friendship which was only dissolved by the death of Dalton. For nine years Hodgkinson's studies and researches led to no apparently useful result; but at length, on the erection of a fire-proof factory, he was engaged to make some experiments, which induced the proposition of a new form of cast-iron girder, differing materially from the form hitherto advocated by Tredgold and others. In the cross section of the girder recommended by Hodgkinson, the upper and lower flanges presented sectional areas proportioned to the power of resistance to compression and to extension respectively. This assumption was verified by careful experiments, conducted by Hodgkinson, at the works of Messrs. Fairbairn and Lillie, at Manchester; and for many years after he continued to conduct investigations of the same nature, either in conjunction with, or at the suggestion of, Mr. William Fairbairn, who, in his various works, has communicated to the world the interesting and practically valuable results of these investigations.

The Manchester Philosophical Society, of which Dr. Dalton was the President, naturally attracted Hodgkinson's attention; and in 1826 he became a Member, having as early as in 1822 contributed some Papers. There are published in the "Memoirs" of that Society seven Papers, chiefly on the mechanical principles of engineering. Eventually, in 1848, he was elected President, and Mr. William Fairbairn, with whom he had unfortunately had some differences, embraced the opportunity of gracefully writing:—

"*June* 28*th*, 1848.

"MY DEAR SIR,—I cannot resist the temptation to congratulate you on your election to the Presidency of the Manchester Philosophical Society. I think the Members have exercised a sound discretion in the selection, and I am heartily glad, after all our squabbles, to find you in a position to which you are so justly entitled.

"I am yours faithfully,
"W. FAIRBAIRN.

"*To Eaton Hodgkinson, Esq.*"

Mr. Hodgkinson soon began to convey to other scientific societies the details of his labours; and in 1840 he communicated to the Royal Society a Memoir on "Experimental Researches on the Strength of Pillars of Cast Iron and other Materials," which was published in the "Philosophical Transactions" of 1840, and won for him the Royal Medal in 1841, and ended in securing his election as F.R.S. in the same year. From that period his reputation increased rapidly, and his formulæ were accepted with such confidence, that they have now a place in all engineering text-books.

When Mr. Stephenson conceived the idea of constructing the Britannia Bridge in the form of a wrought-iron tube, he engaged the assistance of Mr. Fairbairn, whose experiments, commenced in April, 1845, were verified as to their mathematical value by Mr. Hodgkinson in the month of September of that year; and during the subsequent trials and investigations at Millwall and at Manchester, Mr. Hodgkinson gave his assistance. These experiments were important, as confirming the results previously obtained by Mr. Fairbairn, and although Mr. Hodgkinson entertained doubts of the self-supporting principle advocated by Mr. Fairbairn, his mathematical investigations, and his subsequent experiments, nevertheless, proved the correctness of the principle, and thus aided in establishing that which is perhaps the most remarkable event in the history of Engineering science of modern times. For his co-operation in this work, he, in conjunction with Mr. Fairbairn and Mr. Edwin Clark, received a Silver Medal at the Paris Exhibition in 1855, when the great Gold Medal and the Cross of the Legion of Honour were conferred upon Mr. Robert Stephenson.

Mr. Hodgkinson was an active and useful Member of the "British Association for the Advancement of Science," and in the Reports of that Society many of his Memoirs are printed. He was also a Member of the Royal Commission issued to inquire into the application of iron to Railway Structures, and in the Report of that Commission he gave the results of some valuable investigations.

The records of his numerous investigations are to be chiefly found interspersed through the "Transactions" of the British Association for the Advancement of Science, and of the Literary and Philosophical Society of Manchester, as well as in other scientific collections; but the nature of his discoveries may also be gathered from the edition of "Tredgold on the Strength of Cast-iron and other Metals," which he edited, adding a supplementary volume. This edition bears date 1842-46; and subsequent to that period, the experiments for the Britannia and Conway Bridges demonstrated the remarkable fact of the opposite character of wrought to cast-iron, as to the capability to resist the relative forces of tension and compression, and showed the value of the cellular top in a tubular beam. Amongst his earliest writings a Paper on the "Transverse Strain and Strength of Materials" will be found, in the fourth volume of the "Memoirs of the Manchester Society" (Second Series, 1822), in which he put forth his views in opposition to those which were general amongst scientific men, as to the situation of the neutral line in a bent body; and on that subject he was subsequently engaged by Mr. Robert Stephenson, to make a series of experiments, which have not yet been published. In the fifth volume of the same "Memoirs" (1831), are five Papers by him, on the "Forms of the Catenary in Suspension Bridges," of which an abstract was given by the Rev. Dr. Whewell in his "Analytical Statics" (Cambridge, 1833), and an amplification by the Rev. Canon Moseley in his "Mechanical Principles of Engineering; two Papers "On the Chain Bridge at Broughton, Manchester, with an Account of its Failure;" and one on the subject of the strength and form of iron-beams. The Fourth Report of the British Association contains the results of an extensive series of experiments—"On the Collision of Imperfectly-elastic Bodies;" and the Fifth Report, a Paper 'On Impact upon Beams."

It would unduly extend the limits of this Memoir to endeavour to give even the titles of his numerous Papers, of which we may hope to see the most important published in a separate form; and for scientific men and engineers, such a collection would be very useful, as the volumes of the scientific societies in which they are now published are not always accessible. To foreign engineers, who highly appreciate the labours of Eaton Hodgkinson, and who have acknowledged their value in very flattering terms, such a publication would be a great boon.

In 1847 Mr. Hodgkinson was appointed Professor of the Mechanical Principles of Engineering in University College, London; and he subsequently removed from Manchester to the metropolis, to fulfil the duties of his post. He delivered several courses of lectures with success; but his health had already suffered, and during later years his labours were only intermittent. It has been stated that his works were highly appreciated by foreign scientific men; to such an extent was this the case that, in 1851, his name was placed upon the list for nomination as a Corresponding Member of the Institute of France; and strenuous efforts were made by eminent men who recognised his merits, to secure his election.

He was unanimously elected an Honorary Member of the Institution of Civil Engineers in 1851, and nowhere could his practical merits be better appreciated. He was a constant attendant at the meetings, and not unfrequently took a prominent part in the discussions. He was personally held in high esteem by the Members, with a large number of whom he was on terms of intimacy. He was acknowledged to be perhaps the most laborious and careful experimenter who had ever devoted himself to the study of the laws which regulate the strength of materials, and his unselfish conduct in gratuitously giving to the world the result of his investigations was generally admired. He was attached to science for its own sake, and he was well versed in other branches than that to which he specially devoted himself.

In private life he was singularly simple and guileless; and his kindly disposition endeared him to all who had the good fortune to make his acquaintance.

His decease occurred on the 18th of June, 1861, at Eaglesfield House, near Manchester, in his seventy-second year, regretted not only by all who knew him, but by those who had professionally benefited by his labours.

GENERAL SIR CHARLES WILLIAM PASLEY, K.C.B., F.R.S., &c., was born on the 8th September, 1780, at Eskdale-Muir, Dumfries, where he received the rudiments of a good useful education; and in the year 1796 he was appointed to the Royal Military Academy at Woolwich where he pursued his studies with energy, and obtained a commission in the Royal Artillery on the 1st of December, 1797. He was transferred to the Royal Engineers on the 1st of April, 1798, and on the 2nd of August, 1799, he received a commission as first lieutenant in that corps.

For the next ten years he was actively engaged in Minorca, Malta, Naples, and Sicily, and other places, and was intrusted with several confidential missions, and employed in many important services; among others, conveying communications between General Villette and Lord Nelson, in 1804.

Having attained the rank of second captain on the 1st of March, 1805; he was still more actively employed, and served, in 1806, under the Prince of Hesse-Philippsthal in the defence of the fortress of Gaeta, when it was besieged by the French. In the same year he was with Sir John Stuart at the battle of Maida, in Calabria.

He was at the siege of Copenhagen, under Lord Cathcart, in 1807, and was transferred to the division of Major-General Leith, at Oviedo, in September, 1808; where he was employed on dangerous réconnaissance duties for some time, until he was appointed extra aide-de-camp to Sir David Baird, in consequence of his knowledge of the Spanish language, in addition to his professional attainments. He was soon after attached, in the same capacity, to the staff of Sir John Moore, of whom he was a devoted admirer; but he blamed the general principles of his retreat, and he advocated his turning upon his pursuers before his arrival at Corunna, whence, in case of being worsted, there was no retreat save by sea.

His next service was in the expedition to Walcheren; and in 1809 he took part in the siege of Flushing, where he was seriously wounded whilst leading his men to the attack of a battery.

During the forced temporary "inglorious ease" consequent upon his wound, he occupied himself in acquiring a knowledge of the German language, and in reading up his former studies.

In November, 1810, he produced the "Essay on the Military Policy and Institutions of the British Empire," which by the plain common sense view which it took of public matters, at a period of unnecessary despondency, and its manly and cheerful tone, deservedly attracted the attention and elicited the encomiums of the best men of the day.

At this period the Duke of Wellington made strong representations to the home authorities respecting all branches of the army; but more especially as to the defective condition of the Engineer Department in the field. This had long been perceived by Captain Pasley, and whilst in command at Plymouth, he had commenced a system of education of the royal military artificers, which had proved most advantageous to the service. In spite of the usual routine opposition, the system of education advocated by him, and laid down in a treatise written at the time for the use of that department of the service, was adopted at Chatham; and he was appointed Director of Field Instruction with the rank of Brevet-Major, which was followed by the steps of Brevet-Lieutenant-Colonel in 1813, and Lieutenant-Colonel in 1814.

In this latter year he commenced the publication of his useful work on "Military Instructions," which was completed in 1817; and in 1818 he published a volume of "Standing Orders," containing a perfect code of military rules for the duties of all ranks in the army.

At this period his pen was scarcely ever idle, and he produced a number of very valuable treatises for the use of the army, some of which have been reproduced abroad.

In 1831 he brought out a volume entitled "Observations on the Expediency and Practicability of Simplifying and Improving the Measures, Weights, and Money used in this Country without materially altering the present standard," wherein he advocated the decimal division; but he strongly opposed the introduction of the unit or the denominations adopted in France.

The peculiar nature of his military duties almost naturally directed Colonel Pasley's attention to civil constructions, and in 1838, he published his very useful and well-known work "Observations on Limes, Calcareous Cements, Mortars, Stuccos, and Concrete, and on Puzzolanas natural and artificial," which has run through many editions, and has been translated into most of the modern languages. It has also powerfully contributed to the foundation of large commercial establishments for the production of Portland and other cements.

The experience he had attained of exploding gunpowder under water led to his being consulted by the Conservators of the Thames, respecting the removal of two wrecks which materially affected the navigation. Colonel Pasley undertook, and successfully accomplished the work, for which he received the thanks of the Municipal Authorities, and the Freedom of the City of London in a gold box. This success led to his undertaking the removal of the wreck of the "Royal George," at Spithead, and the "Edgar," at St. Helens. During portions of six successive summers, between 1839 and 1844, he devoted himself to these labours, which were ultimately completely successful, not only in clearing the anchorage-ground, but in recovering such a quantity of valuable material, that the operations cost nothing to the nation; for all these services, however, Colonel Pasley neither asked nor received any reward from the Admiralty.

The following characteristic note was written to the compiler of this Memoir, when seeking, for a foreign correspondent, information on firing charges of gunpowder under water.

"My dear Sir, *9th February*, 1855.

"My operations against wrecks will be found in what is now called 'The United Service Magazine,' but was formerly styled the 'United Service Journal.' The numbers for September, 1838, and the 'Editor's Portfolio,' for October, 1838, page 271, contain the account of my operations for blowing up and removing the wrecks of the brig 'William,' and schooner 'Glamorgan,' the former sunk in the Thames near Tilbury Fort, the latter nearly opposite to East Tilbury Church, towards the eastern extremity of Gravesend Reach. In June, 1839, of the same journal, page 183, are further observations on my subaqueous explosions in the Thames. In November, 1839, is a Paper by Captain Basil Hall, R.N., on the capstan of the 'Royal George' recovered by me in September of that year. In January, 1840, page 72; and in February of the same year, page 149; and in March of the same year, page 164; my first operations in the removal of the wreck of the 'Royal George' are described, which were continued every summer till the end of 1843; but no more of my operations were published in the 'United Service Journal,' because the Editor made difficulties about the length of them, and I would not curtail them, as I always noticed the Royal Engineers' officers and privates, of the sappers and miners, as well as the civil divers, and the riggers, or dockyard-men who were more useful, as well as the excellent officers of Engineers Captain Symonds and Hutchinson, which was a great incentive to zeal and activity on the part of all the workmen thus distinguished. In 1844, I removed the wreck of the 'Edgar,' blown up and sunk by accidentally catching fire, off the Mother Bank, at Spithead, in the early part of the last century when not a man was saved of those on board. Lieutenant (now Captain) Barlow, R.E., with the same excellent military workmen, dockyard-men, naval pensioners, and riggers were employed in 1841; but no civil divers were employed as in the commencement of our operations at Spithead. Your correspondent must not attempt simultaneous explosions, or to make use of one conducting wire, trusting to the water for completing the circuit. These expedients were tried repeatedly, in 1843, by Captain Hutchinson, who was very zealous about them; but we lost a great deal of powder by the first, as we never succeeded in firing more than two charges simultaneously out of a greater number, and the cases containing a second charge were generally burst, and the powder spoiled, by the explosion of the first that happened to prove successful. The second of those expedients gave more trouble, and required a battery of double the power to produce the same effect. We, therefore, in all cases, used a separate voltaic battery, and *two* conducting wires to every charge in our operations against the 'Edgar' in 1844.

"I remain, my dear Sir,
"Yours very faithfully,
"C. W. Pasley."

"P.S. My operations from 1840 to 1844, inclusive, were published in a Portsmouth weekly paper, of which I think Harrison was the editor, but I have no copy of them."

In the year 1841 he was removed from Chatham, and was appointed Inspector-General of Railways, the somewhat invidious duties of which he performed with great uprightness and conscientiousness, if not always for the benefit of the public service. He had some "bloodless encounters" with his civil brethren, in which controversial opinions were stoutly maintained on both sides; but amidst all that occurred, Colonel Pasley was universally respected and esteemed, and he certainly did his utmost to perform his duties as well in his civil as in his military capacity. He resigned the post in the year 1846, when he was made a K.C.B. for his services, and henceforth devoted himself to re-editing his various works, and to the introduction of useful apparatus for the Military Engineering service, as well as in advocating the Decimal Coinage system.

His higher steps in the army were Brevet-Colonel in 1830; Colonel of Engineers in 1831; Major-General in the army in 1841; Lieutenant-General in 1851, and General in 1860. The degree of D.C.L. was conferred upon him at Oxford in 1844.

He had been a fellow of the Royal Society since 1816, and he belonged also to the Astronomical, the Geographical, the Zoological, the Statistical, and other Societies; and of the Institution of Civil Engineers, he became an Honorary Member so early as the year 1820, on the proposition of Mr. Telford, seconded by Messrs. Palmer, Field, Maudslay, and Jones—four out of the five founders of the Institution. He was a constant attendant at the meetings, and frequently took part in the discussions, exhibiting a pertinacious determination not to be out-manœuvred, or to be beaten in a fair stand-up fight, if by any tactics or strong argument he could prevent defeat. Among the Civil Engineers he was almost universally popular; and he devoted himself to his civil duties with as much energy as he had previously done to the practice of his own profession.

He was equally popular at the East India Company's Military College of Addiscombe, where he held the position of Public Examiner for sixteen years, up to the year 1855; and the high standard which was reached and maintained by that establishment may, in some degree, be attributed to the energy infused into the officers, and others connected with it, by the good example of Colonel Pasley.

His constitution began to give way for only a short time before his decease, and he may be said to have been well up to within a week before his death, which occurred at his residence, in Norfolk Crescent, Hyde Park, on the 19th of April, 1861, deeply regretted by his relatives; and his memory will long be cherished by his numerous friends, as a most useful and worthy member of society, and a very distinguished and meritorious officer.

Mr. WILLIAM ALLCARD, a descendant of a family well known and esteemed in the Society of Friends, was born in London, on the 30th of June, 1809. At an early age he was placed as a pupil under the late Mr. George Stephenson, at the Steam Engine Manufactory at Newcastle-upon-Tyne, which has since attained such a high reputation. He was there occupied in the Drawing Office, and occasionally assisted in levelling and surveying on the projected lines for the Leeds and Selby and the Newcastle and Carlisle Railways.

In the year 1826 he was transferred to Liverpool, and was placed in charge of the preliminary operations for draining and for forming the Liverpool and Manchester Railway across Chatmoss; and he then had intrusted to him a portion of the works in construction at the Bolton end of the Bolton and Leigh Railway. Early in the year 1828 he was appointed the Resident Engineer, for the middle portion of the Liverpool and Manchester Railway, including the Sankey Viaduct, consisting of nine arches, each of 50 feet span and about 70 feet in height, and the Kenyon Cutting, containing about 400,000 cubic yards of excavation. In the prosecution of these works he remained until the completion of the railway and its formal opening on the 15th of September, 1830, at which he assisted, and took charge of the 'Comet' locomotive engine, with one of the trains forming the procession from Liverpool to Manchester on that memorable and eventful day.

Although at that time he was only twenty-one years of age, yet the responsible positions in which he had been placed, in common with all the pupils of George Stephenson at that period, and the anxious and important duties which devolved upon him, had given him a bearing and a manner much above his years, and had called forth very early his great powers of self-reliance.

Soon after the railway was opened, Mr. Joseph Locke and Mr. Thos. L. Gooch having both left it for other works, the Directors made an arrangement by which the management of the line was divided equally between Mr. Allcard and Mr. John Dixon, who were retained as the Resident Engineers; the former taking charge of the Liverpool end. This important position he held for upwards of two years, during which time he commenced the works of a new tunnel, which was projected to convey passengers into the centre of the town of Liverpool, to what is now the Lime Street Station.

In the early part of 1834 he was appointed the Resident Engineer to the Birmingham end of the Grand Junction Railway, his district extending from Birmingham to Stafford, and he remained in charge of those works till their completion, and the opening of the entire line in July, 1837.

When the maintenance of this railway fell into the hands of the Company, the Directors sought to let it for a term of years, at a certain fixed rate per mile per annum. This contract was undertaken by Mr. Allcard, who was thus the first to engage in a mode of railway maintenance, afterwards followed by many other Companies At a later period Mr. Allcard, jointly with Mr. John Allan, entered into a similar contract with the Lancaster and Preston Railway Company, and he was also the contractor for the permanent way of the Manchester and Sheffield Railway.

In 1841, when the late Mr. Locke (Past President) commenced the construction of the Paris and Rouen Railway, Mr. Allcard and Mr. Buddicom, with Mr. Brassey and the late Mr. William Mackenzie, contracted with that Company for the construction of their locomotives and rolling stock, and established the large and well-known engine-works at Rouen. With the increase of railways in France, this business became one of considerable importance, not merely for the construction of railway rolling stock, but also for contracting for locomotive power, and for working the trains at a fixed rate per mile. This system included the Paris and Rouen, the Rouen and Havre, the Dieppe, the Paris and Caen, and the Cherbourg Railways, and was continued from the respective openings of those railways, until the middle of the year 1861. Although Mr. Allcard took no active part in the operations of the concern after 1847, yet he remained a partner until the period of his decease, which took place suddenly, on the 5th of August, 1861, at the age of fifty-two, and whilst he might still have looked forward to many years of active utility. He was much esteemed in a wide circle of friends, who had been connected with him for a long period, and by whom his decease is sincerely regretted

He only joined the Institution as a Member in 1858, but during his residence each year in London, he took great interest in all the proceedings and in the general welfare of the Society.

MR. SAMUEL CLEGG was born at Manchester, on the 2nd of March, 1781, and after receiving at that place a good education, he enjoyed the advantage of the scientific instruction of Dr. Dalton. He was then apprenticed to Messrs. Boulton and Watt, and at the Soho factory he fully availed himself of the practical instruction and the example of Murdoch and the other able men who at that time, under the supervision of James Watt, directed the great works undertaken by the firm.

At that period Murdoch was practically adapting for public use his invention of lighting by gas. Mr. Clegg followed these experiments and attempts with much interest, and profited so well by the experience he gained, that he was soon practically engaged to adapt the system for lighting the Cotton Mill of Mr. Henry Lodge, at Sowerby Bridge, near Halifax. At that place he early perceived the necessity for some simple process for purifying the gas, and his chemical knowledge readily indicated lime as the best purifying medium, and after much perseverance in modifying the details of the apparatus, he succeeded in producing the Lime Purifiers which, with but little alteration, remain in use at the present time.

At that period Winsor was making an energetic struggle against prejudice and private interest for the introduction of Gas Lighting into London; and Mr. Clegg, perceiving an opening, came to the metropolis. His first active occupation was in lighting, in 1813, the establishment of Mr. Ackermann, in the Strand, which was so successful as to bring him prominently forward, and in 1814 he became the Engineer of the Chartered Gas Company, whose works much needed the direction of a skilful man; his exertions were speedily successful, and Mr. Clegg's reputation was made.

He soon became aware of the disadvantage of payment for gas being made by time, and by the nominal consumption of different kinds of burners, and he directed his attention to a means of measuring the actual consumption. After many attempts to construct a dry meter, which would register satisfactorily, he, in 1816, contrived and patented a Water Meter which has been the basis of all the subsequent improvements in the methods of measuring gas.

For some years he continued to be actively engaged in the construction of Gas Works; or in advising on the formation of new Gas Companies, then springing up in all directions; but in an evil hour he was induced to join an engineering establishment at Liverpool, which was not successful, and giving up all to the creditors of the firm, he had to commence the world afresh. It must be recorded, to his honour, that although he never was an opulent man, he could not rest until he had paid in full all that was due to the creditors of the firm of which he had been a partner.

He was afterwards appointed by the Portuguese Government to an Engineering position of importance, and in that capacity he reconstructed the Mint at Lisbon, and executed several public works, some of which are mentioned in a Paper presented to the Institution of Civil Engineers by the late Mr. S. Clegg, jun.[1]

The Railway epoch opened a new field for Mr. Clegg, and on his return from Portugal, he directed his attention to the question of traction; unfortunately he was fascinated with the Atmospheric system, at the introduction of which he laboured very hard, and he attempted with much ingenuity to overcome the inherent defects of the system. Its failure was a great blow to him, and he never after took any very active part in public affairs.

He was appointed by the Government one of the surveying officers for conducting preliminary inquiries on applications for new Gas Bills, and he occupied his spare time chiefly in contributing to the elaborate History of Gas Lighting published by his son,[2] and he devised a new Gas Meter, which exhibited much ingenuity, but the idea was not fully carried out.

It has been truly written of Mr. Clegg, by a professional friend who knew him well:—"Samuel Clegg earned for himself a world-wide reputation as the founder of a system of artificial lighting that completely revolutionised former methods of illumination, and which, among the many inventions of the present century, yields only to railways and to the electric telegraph in its influence on the social and economic condition of society. Of the importance of this system—which, if not invented, was at least first successfully established by the efforts of Samuel Clegg—some idea may be formed from the amount of capital and labour employed in its operation. In this country alone the capital invested in gas-works is estimated at not less than £30,000,000, in addition to the sums employed in the various trades associated with the supply of gas, including ironfounders, fire-brick makers, tube-makers, brassfounders, meter manufacturers, gas-fitters, &c. It is no small consideration also that all the apparatus employed is of native manufacture, and that every shilling expended is applied in employing the labour of our countrymen. The value of the gas annually consumed in the United Kingdom is estimated at £5,000,000, and the coal used in the manufacture amounts yearly to the enormous quantity of 3,500,000 tons. Nor is the influence of gas lighting on the capital and labour of this country limited to those sums, prodigious as they seem, for the coal and iron used in foreign gas-works are principally derived from England. Such is a brief outline of the extent and influence of the new industry that was mainly created by Samuel Clegg. Winsor, the two Crosleys, John Malam, and many other of his coadjutors in the great work, have long preceded him to the grave; but we have yet left among us Lowe, Neilson, G. H. Palmer, and Grafton, as connecting links with the past—men who strenuously laboured with him whose death we now mourn, in overcoming the obstacles that stood in the way of the success which they ultimately accomplished."

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[1] *Vide* Minutes of Proceedings, Inst. C. E., vol. i. (1841) p. 138.

[2] *Vide* "A Practical Treatise on the Manufacture and Distribution of Coal Gas." By S. Clegg, jun. 4to, plates. London (Weale), 1859, 3rd edition.

Mr. Clegg was a very old member of the Institution of Civil Engineers, which he joined in 1829: in the early and struggling days of the Society he was a constant attendant at the meetings, frequently joining in the discussions; and he never ceased to take a lively interest in the proceedings, and to come among his professional brethren, by whom he was universally respected and esteemed.

"In private life, his natural reserve and diffidence prevented Mr. Clegg from being known and appreciated to the extent which his genius and acquirements would otherwise have commanded; but to his intimate friends he was endeared and respected by his sterling integrity of character, by his affectionate disposition, and, by a happy flow of spirits, which he retained to the last. His was not a death of disease and pain: it was the wasting away of the lamp of life, which, after having, during a long career, shone brightly on the world, flickered and expired" on the eighth day of January, 1861, at the mature age of seventy-nine years.

Sir WILLIAM CUBITT, F.R.S., was born in the year 1785, at Dilham, in Norfolk, where his father was a miller. The small amount of early education afforded to him was obtained at the village school; and subsequently, when his father removed to Southrepps, where he rented the mill, young William ingratiated himself with the Rev. Erasmus Drury, the curate of the parish, and, obtaining access to his library, and afterwards to that of the Rev. J. Humphrey, of Wroxham, he well stored his mind with useful information.

At an early age he was employed in the mill, and having exhibited considerable aptitude in the repairs of the machinery, he was in the year 1800 apprenticed to one James Lyon, a cabinet-maker and joiner at Stalham, from whom, after a rude service of four years, he gladly parted, having, however, acquired great dexterity in the use of tools, as is evidenced by the neat construction of several articles of furniture still in the possession of some of his old friends in Norfolk.

During the period of the apprenticeship of the son, the residence of the father was once more changed to Bacton Wood Mill, where, in the year 1804, young William joined him, and in his leisure hours commenced his first practical invention by an attempt to construct a machine for splitting hides; this machine, although unsuccessful, exhibited considerable mechanical talent. Determined, at length, to commence life on his own account, he joined an agricultural machine-maker named Cook, who resided at Swanton, where they constructed horse threshing-machines, and other agricultural implements, with some success. At this period he became celebrated for the accuracy and good finish of the patterns made by him for the iron castings for these machines.

His attention was at this time naturally directed to windmills, which he was frequently employed to repair, and finding the difficulty of managing, during stormy weather, the large sails then introduced, he was led to invent the self-regulating windmill sails, now in universal use, which were patented in the year 1807, at which time he had settled at Horning, in regular practice as a millwright.

He next commenced the construction of machines for draining the marshes in the immediate vicinity of his residence, and several of these machines, mounted on tripod frames of cast-iron, are still in existence. He obtained considerable employment at this period, but as his progress was not so rapid as he desired, he in the year 1812 sought and obtained an engagement in the then rising works of Messrs. Ransome, of Ipswich, where he soon became the chief Engineer of the concern, to which he afforded great assistance. He remained there for nine years, and during that period was engaged in several engineering works of interest, such as improvements in the port of Ipswich,[1] and in the gasworks of that town. His engagement under the Messrs. Ransome led eventually to his becoming interested in the concern, a position which he held until the year 1826, when his numerous engagements as a Civil Engineer rendered necessary his removal to London.

Before this period, Mr. Cubitt's attention had been directed to the question of the employment of criminals; and for the purpose of utilizing the labour of convicts he invented the treadmill, with the object of using the power for grinding corn, pumping water, &c., not at first contemplating the use of the machine as a means of punishment. This invention was brought out about the year 1818, and it was immediately adopted in almost all the principal gaols of the kingdom.[2]

For some time anterior to his settling in London, Mr. Cubitt had been extensively employed as a Civil Engineer, and among his early Reports are those of 1814, 1820, and 1822, on the

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[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xx., p. 4, *et seq.*

[2] In the year 1822 an account of the treadmill was published by the Society for the Promotion of Prison Discipline, wherein the machine is mentioned as "invented by Mr. William Cubitt, of Ipswich."

Norwich Navigation; and it was in the latter year that he first came in contact with Mr. Telford.

From the period of his removal to London, Mr. Cubitt was engaged in almost all the important works of the time, and his opinion and evidence were sought on all the great questions, such as ports, harbours, canals, the improvement of rivers, or the construction of railways, and he was occupied in designing bridges.

It would be impracticable, within the limits of this Memoir, to enumerate the numerous works upon which Mr. Cubitt was engaged, as there was scarcely a question of engineering interest upon which his opinion was not sought either by the promoters, or by the opposition; and his appearance in the Committee Rooms at Westminster, with his never-forgotten slide-rule in his hand, was familiar to all the profession. A few only of his principal works may, however, be alluded to. He was extensively engaged in Canal Engineering, and the Oxford Canal and the Birmingham and Liverpool Junction Canal are among his works under this head. The improvement of the River Severn was designed and carried out by him; and he was frequently consulted and made many important reports on the Rivers Thames, Tyne, Tees, Weaver, Ouse, Nene, Witham and Welland. He was also a Member of the Commission for the improvement of the Shannon, in which his judgment and experience were of material service.

The Bute Docks at Cardiff, the Middlesborough Docks and Coal Drops[1] on the Tees, the Black Sluice drainage, and its outfall sluice at Boston Harbour, are among his works.

On the introduction of railways, the evidence of Mr. Cubitt as a practical mechanic was sought with good effect in Parliamentary contests; and, as Engineer-in-Chief, he constructed the South-Eastern Railway, where he adopted the bold scheme of employing a monster charge of eighteen thousand pounds of gunpowder for blowing down the face of the Round Down Cliff between Folkestone and Dover, and then constructing the line of railway along the beach, with a tunnel beneath the Shakespeare Cliff.

On the then Croydon Railway, at the desire of the Board, the application of the atmospheric system of traction was undertaken by him, and he certainly did all in his power to induce its success.

On the Great Northern Railway, to which he was the Consulting Engineer, and which was constructed by his son, Mr. Joseph Cubitt (M. Inst. C.E.), he endeavoured to introduce all the undoubted improvements of other lines, and with great success.

His engineering efforts were not confined to the United Kingdom, and his opinion was frequently sought for on the Continent. Among other matters, he was consulted by the Hanoverian Government on the subject of the Harbour and Docks at Harburg. The works for supplying the city of Berlin with water were constructed under his advice and direction, and at the great discussions at Paris relative to the rival Companies proposing to construct the Paris and Lyons Railway, Mr. Cubitt, accompanied by the author of this Memoir, made a careful investigation of the country, and his Report exercised considerable influence on the ultimate determination of the question.

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[1] *Vide* Minutes of Proceedings Inst. C.E., vol. v., p. 248.

On the completion of the railway to Folkestone, the establishment of steamers between that port and Boulogne was a natural consequence, and the improvement of the harbour was inevitable. Then followed the proposition for the construction of a line of railway from Boulogne to Amiens, there to join the Great Northern Railway of France, and to this Mr. Cubitt became the Consulting Engineer, the works being under the immediate direction of Monsieur Bazaine, Ingénieur des Ponts et Chaussées.

Among Mr. Cubitt's latest works were the two large floating Landing Stages at Liverpool, one at St. George's Pier, and the other at the Albert Parade; these works were novel in their details, and most successful in their operation, and the latter still considerably exceeds in dimensions any other work of its kind.

His last work was the Bridge for carrying the London Turnpike Road across the Medway at Rochester. This was founded on cast-iron cylinders, sunk by the then novel pneumatic process, and carried down to the depth of 55 feet below high water.

In the year 1849, when the International Exhibition was under discussion, it was felt that it would be essential to have some good authority to refer to with respect to the construction of the building to be erected in Hyde Park. Sir Robert Peel made inquiry respecting the qualifications of the President of the Institution of Civil Engineers, and being satisfied on the points in question, the definitive appointment of the Royal Commissioners was deferred until after the election of Mr. Cubitt as President, in January, 1850. An arrangement was made forthwith, by which he undertook very active and responsible duties in connection with the construction, and he executed them so satisfactorily that at the expiration of his services in 1852, Her Majesty was pleased to confer upon him the honour of Knighthood, which he had more than earned by his earnest and intelligent conduct of that large and novel work. When the total subversion of the original plan for the building, as designed by the Committee, was proposed to Mr. Cubitt, he did not hesitate to examine the plan submitted to him by Mr. (now Sir Joseph) Paxton, through the intervention of a mutual friend; nor did he decline, when he had maturely considered the plan and the details of construction as given by

Mr. (now Sir Charles) Fox, to give his adhesion to it, and to join in proposing it to Prince Albert. How successful was that novel and unique construction need not here be mentioned; but it must be maintained that to Mr. Cubitt's good mechanical and constructive knowledge, his cool and mature judgment, and his confidence in the plans decided upon, the ultimate triumphant success was in a great measure due.

He became a Fellow of the Royal Society in the year 1830;—he was also a Fellow of the Royal Irish Academy, Member of the Society of Arts, and of other societies.

Labours such as have here been shadowed forth rather than described would suffice to wear out the strongest constitution, and Sir William Cubitt, who had never been a robust man, felt it necessary in 1855 to retire in some degree from the active exercise of the profession; and in 1858 he ceased to give any attention to business; he continued, however, to take an interest in the proceedings of the Engineering world until his final illness, under which he sunk on the 13th of October, 1861, in his 77th year, at his residence on Clapham Common.

Sir William Cubitt joined the Institution of Civil Engineers as a Member in the year 1823; he became a Member of Council in 1831, was elected Vice-President in 1836, and held the post of President in 1850 and 1851. At the period of the great changes introduced into the constitution of the Institution he took a very active and useful part, and throughout his career he was an earnest friend of the Institution, which he considered to be the great bond of union of the members of the profession.

Sir William Cubitt was among the last surviving self-made Engineers, and few men laboured more honestly and uprightly to obtain well-deserved eminence.

Mr. NICHOLAS OLIVER HARVEY was born in the year 1801. When young he was for a short time with his uncle, the late Mr. Henry Harvey, the proprietor of the Hayle Foundry, Cornwall. Subsequently he became a pupil at the Eagle Foundry, Birmingham, then managed by the late Mr. W. Brunton (M. Inst. C.E.), where he remained until he was about twenty-one years of age. He then returned to Hayle, to assist in the management of the foundry, where he had the advantage of working with Trevithick and with Wolff, and derived great benefit from this association; many of the improvements in steam machinery, introduced since that time, having been then discussed in advance of their present adoption. As an example, Mr. Harvey has been heard to relate, that Trevithick, whose tubular boiler is still the one universally adopted for stationary engines, discussed the advantage of using small tubes, in order to shorten the boiler, and speculated how far the flame would extend along the barrel of a fowling-piece, before the heat of the ignited gas was absorbed. Mr. Harvey assisted in the construction of the first double-cylinder engine, designed by Wolff, and made at Hayle; and he took part in the experiments which were tried at the Great Alfred Mine, in Cornwall, and which convinced Wolff, that the combined cylinder engine was less economical than the single-acting engine for pumping water.

Mr. Harvey's health, at no time very robust, now failed, and he consequently visited London for relaxation and improvement. Whilst there he was introduced, by the late Mr. Samuel Seaward (M. Inst. C.E.), whose acquaintance he had made at Hayle, to the proprietors of the Fijnoord Engineering Works, Rotterdam, from whom he accepted a situation. Whilst in Holland, he was engaged in the construction of some of the first boats built there for navigating the Rhine. Many experiments were tried for adapting shallow boats to the river, both for towing and for passenger traffic. These included many varieties of form and of construction, both in iron and wood, and from the notes made at the time, in the infancy of that branch of Engineering, it would appear, that the amount of success attained, with the limited means at their disposal, was very remarkable. Almost everything in iron was the subject of experiment, both as to its durability, particularly for marine boilers, and as to its strength; and Engineers in those days had to design, with the pencil in one hand and the hammer in the other. It may be remarked, that Mr. Harvey there successfully applied the feed-heater around the funnel, which nearly thirty years afterwards proved so disastrous on board the 'Great Eastern.' After residing for about five years in Holland, he accepted an engagement with a Prussian firm, to establish works for boat-building and for the manufacture of marine engines in Sterkerade, now among the most important in Prussia. There he built several boats; and when the first of them was constructed, Mr. Harvey was compelled to turn hammerman, and to forge the paddle-shaft. He also introduced the Cornish pumping-engine into that neighbourhood, with great success, for draining mines.

When he was about thirty-three years of age he returned to Cornwall, to take the management of the Hayle Foundry. His attention was shortly after drawn to the machinery then employed for supplying London with water, and he endeavoured to introduce the Cornish pumping-engine, of the economical working of which he had such extensive experience in mines. After a time he succeeded in obtaining a contract, to erect an 80-inch cylinder engine for the East London Waterworks Company at Old Ford, and for this engine he, with Mr. West (M. Inst. C.E.), constructed their double-beat valve, which afterwards came into general use, and without which, at that time, these large pumps could not have been employed, the shock being so great with the common valves then in use. This engine, an account of the performance of which was published by Mr. Wicksteed[1] (M. Inst. C.E.), proved very successful, the consumption of fuel being reduced more than one-half, and it is still at work. Subsequently, other engines on the same principle were erected, and before his death, Mr. Harvey had the satisfaction of seeing the Cornish system generally adopted; the greater number of these engines being manufactured at the Hayle Foundry, of which he had become the principal proprietor. He also erected pumping-engines for supplying Liverpool, Manchester, and several other towns with water; and the large engines for draining the Haarlem Lake were principally manufactured under his superintendence. All the work undertaken by him was finished regardless of cost, money-making being a secondary consideration. He was a man of great practical experience, both in designing and in manufacturing engines, and was very ready in invention. He was much beloved by those connected with him, and respected for his uprightness, hospitality, and truly genial nature. His death occurred in the year 1861, in his sixty-first year, leaving a widow and a family of young children to mourn his loss.

He joined the Institution as a Member in the year 1839, but his constant absence from London prevented his regular attendance at the Meetings.

MR. JOSEPH MAUDSLAY, the fourth son of the late Mr. Henry Maudslay, the celebrated Mechanical Engineer, and founder of the well-known firm of Maudslay, Sons, and Field, was born in London on the 17th September, 1801. It was originally intended to bring him up as a ship-builder, for which purpose he was placed with the late Mr. William Pitcher, at Northfleet; but circumstances frustrating that intention, he was taken into the establishment at Lambeth, where he eventually became a partner in the firm. He always retained his fondness for naval architecture, and his attention to the lines of vessels was of great utility, in the determination of the necessary motive power for their propulsion.

Mr. Maudslay was one of the first to perceive the advantages of direct-acting engines for marine purposes; and in 1827, he patented an arrangement for applying to the engines with oscillating cylinders, (introduced by the late Mr. A. Manby in 1819,) the ordinary slide valve worked by an eccentric. A pair of these engines was, in 1828, fitted on board the 'Endeavour,' a small vessel which plied for many years between London and Richmond. Several pairs of these engines were fitted in 1832 into iron vessels built by Messrs. Maudslay, Sons, and Field, by order of the East India Company, for the navigation of the Ganges. The prejudice against the use of oscillating cylinders was, however, so strong, at that period, that other forms of direct-acting engines were devised, and in 1839, in conjunction with the late Mr. Joshua Field, (Past-President, Inst., C.E.,) he patented the direct-acting engine with double cylinders, which has been extensively adopted by the British as well as by foreign Governments, for vessels of war, and has also been used by the mercantile marine. This prejudice has since been removed, and oscillating engines are now generally regarded as the most successful arrangement of direct-acting engines for paddle-wheel propulsion, although it is still argued by some Engineers, that for very large powers the fixed double cylinder engines are preferable.

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[1] *Vide* "An Experimental Inquiry concerning the Cornish and Boulton and Watt Pumping Engines." By Thomas Wicksteed. Weale, London, 1841.

In 1841 he also patented the annular cylinder engine, which has been successfully used in several of the fast packets between England and France and the Channel Islands.

Mr. Maudslay was so much impressed with the necessity for employing an improved class of vessels for the different packet stations, that he, in conjunction with Messrs. Ditchburn and Mare, and the late Mr. John Hayward, of Dover, built, in 1843, the 'Princess Alice,' a vessel of 274 tons, fitted with annular engines of 120 H.P. power, and having tubular boilers. This vessel, now an Admiralty yacht at Devonport, may be considered as the type of the fast packets since placed on the different Channel stations, and was soon after purchased by the Government, for the service between Dover and Calais. She was speedily followed by four other vessels, which were built in 1844, and were fitted with similar engines of 120 H.P. for the service between Folkestone and Boulogne, in connection with the South Eastern Railway, whilst others of somewhat larger power were constructed for the Southampton and Channel Islands station, and for foreign Governments.

Mr. Maudslay took great interest in the different experiments tried on board H.M.S. 'Rattler,' which was fitted with engines by his firm in 1841, to test the applicability of the screw propeller, and he early became convinced of the necessity of abandoning wheelwork for driving the screw, and of adapting the engines to work with the number of revolutions necessary for driving the screw direct. To test this he, in conjunction with his partners, built the 'Water-lily,' a vessel of 184 tons, and fitted her with direct-acting engines of 50 H.P. Numerous experiments were tried at considerable cost to the firm, in this vessel, with different forms of screws, before she was sold to the Austrian Government for a steam-yacht. The application of engines for driving the screw direct was so successful on board this vessel, that, on the advice of Mr. Maudslay, the Admiralty had one of the full-powered screw vessels ordered in 1846 fitted with the direct-acting engines; and the 'Niger' was so fitted by Messrs. Maudslay, Sons, and Field, with engines of 400 H.P. These engines made seventy-five revolutions per minute, which was considered a great speed at that time, and the correctness of Mr. Maudslay's views has been since shown, by the almost universal adoption of direct-acting engines for driving the screw, not only in the Admiralty Service, but also in the Mercantile Marine.

Mr. Maudslay likewise devoted much time and thought towards the adaptation of the screw to all circumstances in which vessels might be placed; and in 1848 he patented a feathering screw, for the purpose of enabling the vessel to proceed under sail alone, without the resistance caused by dragging the ordinary screw through the water. Feathering screws were accordingly employed in 1850 in three vessels of 530 tons burthen and 100 H.P. belonging to the General Screw Steam Shipping Company, and the success was such as to induce the Company to apply propellers on that principle to their fleet of large vessels of 1,800 tons burthen and 300 H.P. These screws answered so well on the voyages to and from Calcutta and Australia, and induced so large a saving of fuel, when the working of them became properly understood, that they have been constantly employed since that time.

In 1857, Mr. Maudslay patented an arrangement of direct-acting annular-cylinder screw engines, which, with his patent feathering screw with differential pitch, was applied with great success to Sir Henry Oglander's yacht 'Firefly,' of 20 H.P. and 200 tons burthen; and early in the year 1862 he had a new yacht of 110 tons and 20 H.P., built and fitted with a similar screw for his own use. The vessel, which was built on lines of his own design, formed the subject of a short Paper read before the Institution of Naval Architects in the year 1860.[1]

Mr. Maudslay was a man of singularly upright and honourable views; no personal considerations ever having sufficient weight to induce him to diverge from what he considered to be the proper course. This in matters of business assumed at times an apparently too rigid tone, but eventually he was generally admitted to be right in his views. Those who were only acquainted with him in his professional capacity knew but half his worth. Of a warm and genial nature, and peculiarly happy in his domestic life, he loved to diffuse around him the benevolent and kindly emotions by which he himself was actuated; and although for the last eleven or twelve years of his life his sufferings were of the most acute and painful character, they had not the effect of ruffling his temper, nor of disturbing the cheerfulness so natural to him, and which was never more marked than when surrounded by his family and friends.

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[1] *Vide* Transactions of the Institution of Naval Architects, 1860, vol. i., p. 54.

His name must now be enrolled on the list of those useful men whose labours have so largely contributed to the honour and prosperity of their country. Eminent in a professional and estimable in a personal point of view, he will be remembered with respect by those who knew him in his ordinary relations to society, whilst, as an affectionate husband, a fond father, and a true friend, his memory will long be cherished in that family circle where the true character only is fully and properly estimated.

Mr. Maudslay became a Member of the Institution so early as the year 1833, and until the state of his health prevented his attendance at the Meetings, he took great interest in the proceedings. His decease occurred on the 25th of September, 1861, only a few days after entering on his sixty-first year.

MR. JOHN McVEAGH commenced his professional career as a Civil Engineer under Sir John Macneill (M. Inst., C.E.), on a line of railway, between Drogheda and Belfast. He then superintended the construction of various Roads, Bridges, and Lime Works in the neighbourhood of Belfast, and was afterwards employed under Mr. Thompson, C.E., of Glasgow in the construction of a bridge over the river Kelvin near Glasgow, in taking soundings and preparing a chart from Port Glasgow to Gourock Bay below Greenock Bank; and in making surveys and taking levels for a proposed canal from Loch Lomond to form a junction with the Forth and Clyde Canal at Bowling Bay. He was then engaged under the late Mr. Errington (M. Inst., C.E.), in the construction of the Greenock and Glasgow Railway, in the preparation of the drawings, for a Landing Stage for deep-water vessels at Greenock, and in the construction of the Docks at that port. He also designed, under the direction of Mr. Errington, plans for a breakwater to be placed on Greenock Bank. Subsequently, he was engaged under Messrs. Locke and Errington in preparing the plans and sections, and carrying the bills through Parliament, of the Lancaster and Carlisle Railway, the Caledonian Railway, &c., from which period, until the time of his death, which took place at Southfield, Liberton, near Edinburgh, on the 17th of August, 1861, he was unremittingly employed professionally in France, Holland, and Spain, as well as in various parts of the United Kingdom. He was also employed for some time in preparing drawings for the extension of the dock accommodation at Sutton Pool, near Plymouth—a work which, from want of sufficient funds, was not fully executed. Upon the portion which was carried out, the resident Engineer was the present Sir Charles Hartley (M. Inst. C.E.), the Engineer of the works now being executed, under the joint commission appointed after the Crimean war, at the Sulina mouth of the Danube.

Mr. McVeagh was constantly occupied during a long and active professional life; and it is a source of regret that all attempts to obtain materials for a proper memoir should have proved abortive. He only joined the Institution as a Member in the year 1858, during the Presidency of the late Mr. Locke, M.P., by whom he was much esteemed.

MR. JOHN PLEWS was born at Thornton Steward, Yorkshire, on the 1st of May, 1795. He was the son of a farmer, with whom he remained until 1812, when having attained his seventeenth year, and determining to make use of the mathematical education he had received, he came up to London, and was engaged under the important firm of Messrs. Jolliffe and Banks, contractors, who at that time were building Waterloo Bridge, and where he remained until its completion in June 1817. He soon gained the confidence of his employers, and he continued with the firm until 1835, in which year Messrs. Jolliffe and Banks both died. Under their direction, Mr. John Plews had the principal management of the large works in which they were for so many years engaged, and amongst which were the building of Southwark Bridge;—the sea-wall in front of the Custom House, London;—the Hermitage entrance to the London Docks;—the sea-wall in front of the Victualling Office, Deptford;—the sea-wharf walls, basins, timber slips, &c., at her Majesty's Dockyard, Woolwich;—the new London Bridge;—the bridge over the Serpentine, in Hyde Park;—the bridge over the Thames, at Staines, Middlesex;—the sea-walls, graving-docks, basins, mastponds, &c., at her Majesty's Dockyard, Sheerness;—the straight cut, five miles in length, through the sand in Sutton Wash, for the river Nene, for the North Level Drainage Commissioners;—and many other extensive and important works.

Sir Edward Banks died in 1835, leaving Mr. Plews one of his executors, in conjunction with Mr. R. L. Jones, the chairman of the London Bridge Committee, and Mr. Bevan, banker, Lombard Street, to wind up, not only his private affairs, but likewise all the unsettled accounts of the partnership of Jolliffe and Banks, which Mr. Plews accomplished with the utmost satisfaction to all the parties interested.

In the latter part of the year 1835, Mr. Plews contracted with the London Dock Company to put in a new stone invert, and to underpin the outer wing-walls of the Shadwell entrance of their docks, extending from the gates to the river; a difficult work, which he executed to the satisfaction of the Company and their Engineer. He was afterwards engaged by the Austrian Government to proceed to Lower Hungary, to report on the practicability of building the bridge over the Danube, from Buda to Pesth, which has since been accomplished. It was necessary that he should be present to see the extent of the floods at the breaking up of winter; and on this occasion, during his stay at Pesth, when the ice broke up, the water came pouring from the mountains with greater violence than had ever been known; the river overflowed, and swept away a great portion of the lower part of the town, drowning nearly twelve thousand persons. The inn in which Mr. Plews was staying being a heavy substantial building, forming the corner of two streets, fortunately withstood the torrent, although the water rose up to the first floor, and immense blocks of ice were dashed against the corner of the house with such force as to shake the whole fabric. In this perilous position he remained for several days, until the water had so far subsided that it was possible to guide a boat upon it, when Count Szechenyi released him.

Mr. Plews held for about sixteen years the appointment of Engineer for the Cardiff Docks, for the late Marquis of Bute, and afterwards, in conjunction with Sir John Rennie (Past President Inst., C.E.), he designed and executed the new docks at that port; and on those works Mr. John Plews, jun. (M. Inst., C.E.) was appointed the resident Engineer.

Mr. Plews also designed the Northumberland Docks, in the river Tyne, below Newcastle, and they were built under his direction, his son being the resident Engineer. The "Newcastle Journal" of October 26, 1857, gave the following account of these works:—

"OPENING OF THE NORTHUMBERLAND DOCK ON THE TYNE.—On Thursday afternoon the Duke of Northumberland opened the Northumberland Dock, on the Tyne, by laying the last stone. These important works are the first that have been undertaken by the River Tyne Improvement Commissioners, and are situated about half a mile above Shields harbour, on the north side of the Tyne. The area of the dock is fifteen acres, and the cost of construction is £200,000. The money for the construction of the dock has been raised by the Commissioners on bonds, and, when principal and interest are paid, the dock will be free and the fees will be abolished. The area enclosed by the dock has long been used as a shipping place for Northumberland coals, and the Engineers—Mr. Plews, of London, and his son Mr. John Plews—have constructed the whole of the works without stopping the shipping of coals for one day. The dock will accommodate 400 sail of vessels, and 1,400,000 tons of coals are annually shipped from the shores now enclosed. There is eighteen feet of water on the dock-sill at neap, and from twenty to twenty-four feet at spring tides. After performing the ceremony of laying the stone, which was done in the presence of a large company of the leading merchants and shipowners of the port, a deputation of seamen waited upon his Grace, and expressed their thankfulness for the munificence he had exhibited in erecting a home in the port for their accommodation. His Grace hoped that the institution would benefit them as a body, and that by and by, when the nautical school was opened, every sailor lad that belonged to the port could have the chances of an education to help him on in the world. The Commissioners entertained a large company in a spacious marquee; the Duke of Northumberland presided. Amongst the speakers were Mr. Ridley, M.P., Mr. Ingham, M.P., Mr. G. Hudson, M.P., Mr. Joseph Cowen, the chairman of the Commissioners, Mr. Hugh Taylor, the chairman of the Coal Trade Committee, and other gentlemen. Mr. Thornbury, of Wellingborough, the contractor for the docks, also entertained several hundred ladies and gentlemen, and the day was celebrated with great festivity."

After so many years of active employment, he desired to retire in favour of younger members of the profession, but he could not lead an inactive life, and thus during the latter part of his career, Mr. Plews occupied himself in the conduct of the affairs of the parish of St. Mary, Lambeth, where the services he rendered were fully appreciated, and the esteem in which he was held was demonstrated, at the period of his decease, by most complimentary resolutions of the parochial authorities, who dwelt with justice on his "faithful service in the administration of parochial affairs, his honest and straightforward course of action, added to his practical and sound business habits, and his kind and generous heart, which had endeared him to all with whom he came in contact."

Mr. Plews died at his residence in the New Road, Kennington, Surrey, on the 23rd of June, 1861, at the age of sixty-six years. He was one of the last of a race of useful, hard-working men, of the early part of this century, whose life was spent in the execution of durable public works which will remain for ages. His uprightness of character was fully appreciated by all with whom he came into contact, and his sound professional knowledge caused his opinion to be sought on many occasions, when the works were ultimately intrusted to other Engineers.

He only joined the Institution of Civil Engineers as a member in the year 1856, and he attended the meetings as often as his engagements would permit.

MR. JAMES RALPH WALKER, the grandson of the late Mr. Ralph Walker, the Engineer of the East and West India Docks and of other important works, was born near London on the 3rd August, 1829. He was educated at the Grammar School of Falkirk, in Stirlingshire, and at the High School and University of Edinburgh, at all of which institutions he distinguished himself by his application and intelligence. After being from the year 1847 a pupil of Mr. J. R. McClean (Vice-President Inst., C.E.), he was employed by the late Mr. Rendel, (Past-President Inst., C.E.), on the Calcutta and Delhi Railway, during the years 1852 and 1853. From the year 1853, he was employed by Messrs. Walker, Burges, and Cooper, in their office, and afterwards as Resident Engineer under them, at the Netherton Canal and Tunnel, Staffordshire, on the subject of which he presented a Paper to the Institution, which was read on the 7th February, 1860,[1] and for which he received a Telford Premium. From the year 1859, he was employed by Messrs. McClean and Stileman, as Resident Engineer, on the South Staffordshire Railway, and other works, in making the surveys for the proposed embankment on the north side of the Thames, and in the laying-out of works connected with iron mines at Hartington, in Derbyshire, where he died at the age of thirty-two years, after a few days' illness, on the 6th September, 1861.

He had made good use of his time and of the opportunities afforded him, and by his steady attention to his duties had secured the esteem of his employers and of all with whom he was brought into contact. He joined the Institution as a Member in the year 1859, and took ample advantage of the instruction afforded by the Meetings.

MR. JOHN WARD was born at Newlands in the parish of Bywell, St. Peter, in the county of Northumberland, on the 7th of January, 1811. He was brought up by his father to his own trade, that of a wheelwright; but having, like many of the natives of that part of England, a strong mechanical turn, he soon became dissatisfied with the work upon which he was engaged, and he bound himself apprentice to Messrs. Robert and William Hawthorn, engineers, of Newcastle-upon-Tyne. After completing his term of service in their locomotive engine-works, he obtained the situation of engine-wright at Haswell Colliery, in the county of Durham, when Mr. T. E. Forster (M. Inst. C.E.) was grappling with the most formidable difficulty ever encountered in coal-mining in the North of England, sinking through the deep quicksand underlying the great magnesian limestone. During the course of some repairs to the pumping-engine, the pump-spears fell down the shaft, and killed one of the engine-wrights. This accident was the cause of Mr. Ward quitting the employment of the Haswell Company, an attempt having been made, unfairly, as he considered, to fix him with the responsibility of having left the pump-spears improperly secured.

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[1] *Vide* Minutes of Proceedings Inst. C. E., vol. xix., p. 263.

The Butterley Iron Company then engaged him in their engineering works near Alfreton, Derbyshire, and he was employed under their engineer, Mr. Joseph Glynn (M. Inst. C.E.), in the execution of the iron bridge over the River Ouse, at Haddlesey, in Yorkshire, and also on several of the works designed by the same engineer for draining the fens of Cambridge and Lincoln and in other parts, by the application of steam power. He was then sent out as engineering manager for the firm of Messrs. George Jessop and Co., of the Phœnix Ironworks at Calcutta, where he arrived about the end of the year 1848. On the retirement of the Messrs. Jessop from the concern, Mr. Ward, in conjunction with Mr. Webber and Mr. Francis, carried on the works for some time, but eventually Mr. Ward resigned his situation with the manufacturing branch, and acted only as their consulting engineer. He had long been aware of the necessity for additional steam power for towing ships on the Hooghly—to that he directed his attention, and commencing with the "Lion" and the "Vulcan" steam-tugs, he afterwards purchased in England a more powerful vessel, the "Phœnix," for which he reconstructed the engines of a ship of war. Upon the commencement of the East Indian Railway, Mr. Ward took a contract for seventy miles of the line, near Patna, including a long brick viaduct across the River Soane. In the course of the summer of 1856 he came to England, and when he returned, took out with him several brickmaking machines and small bucket-dredgers upon the principle of the marine dredging engines, adapted by himself for the purpose of rapidly and cheaply excavating the brick (or cylinder) wells upon which the foundations of the bridges are usually constructed in India. The breaking out of the Indian mutiny putting a stop temporarily to the railway-works, caused severe inconvenience to many of the contractors, and like the others, Mr. Ward was obliged to discontinue his contract. He concurred with the other Europeans in organizing the volunteer force for the defence of Calcutta, and served in the corps until he was seized by the disease to which he fell a victim, and he died at Calcutta on the 10th of January, 1858. Mr. Ward was a thoroughly good mechanic of the old millwright class; he worked both in wood and iron equally well, and his constructive ability enabled him to undertake and carry on an entirely new kind of work in a country where mechanical appliances were almost unknown, and to execute with the comparatively untaught Indians constructions previously considered to require the power and energy of Europeans.

Mr. Ward joined the Institution as a Member in the year 1856, and took much interest in the proceedings. He enjoyed the reputation of being a highly honourable man, of a retiring disposition, confident in his own powers, but unwilling to obtrude his opinion, or to influence others, by the parade of his experience. He was highly esteemed in India, and his premature decease was much regretted.

MR. GEORGE AITCHISON was born on the 21st of December, 1792, at Leyton, Essex, and received his education at schools in the neighbourhood. In 1808, he was apprenticed to his father, who was a builder, and with him he worked for some years. In 1813 he was articled to Mr. Henry Hake Seward, Architect, with whom he remained until 1823, when Mr. Seward resigned his private practice for the Surveyorship of Greenwich Hospital. During this period, Mr. Aitchison had become a student of the Royal Academy, and had sent in designs for London Bridge, and for the Caledonian Chapel. From 1823 to 1826 he was the principal clerk to Mr. Thomas Hardwick. In 1826 he was assistant to Mr. Thomas Lee, and in 1827 he accepted the office of Clerk of the Works to the St. Katharine's Dock Company, on the recommendation of Mr. P. Hardwick, R.A. (M. Inst. C.E.), then Surveyor to the Company. On the 25th October, 1828, the Docks were opened, and from that time he was permanently retained in his appointment. During the construction of the Docks he became acquainted with Mr. Telford, at whose suggestion he joined the Institution of Civil Engineers as an Associate in the year 1828.

When it was determined to construct a railway from London to Birmingham, a system of books and returns for the works was required; and as many of the Directors were also on the Board of the St. Katharine's Docks, they, knowing his skill in such arrangements, appointed Mr. Aitchison for this purpose. He was also appointed architect to the Road Stations, and was requested to give the late Mr. R. Stephenson, M.P. (Past President Inst. C.E.), the aid of his experience in carrying out the structural works on the line. In 1844 he was elected by the magistrates to the New District Surveyorship of Woolwich. In 1848 he built the Irongate Wharf, probably the first fireproof warehouse erected in London; and he was shortly afterwards appointed Architect to the St. Katharine's Dock Company, for whom he erected the Warehouses E, H, and I,—the new Engine and Accumulator Houses, and a new story over the whole of the Cutler street Warehouses. He was likewise elected Architect to the Founders' Company, and in addition to a large private practice, he was named the consulting Architect to several parishes. In 1853 he was employed by the Directors of the Union Bank of London to alter and enlarge their premises in Princes Street; and as there was a difficulty in obtaining sufficient light, he applied to the manager's room a screen of iron and glass, which was so satisfactory, that it attracted general attention, and has since been extensively applied. He also enlarged the building for the Pall Mall branch of the same bank, and constructed the branch establishment in Fleet Street. He erected many private houses, as well as several wharfs and warehouses on the River Thames; he was employed by her Majesty's Commissioners of Customs, to prepare drawings for a jetty to be erected at the Custom House; and was consulted by the Government on the Bill of the Metropolitan Building Act of 1855.

These diversified labours at length told upon his constitution, and in 1858 he had a slight attack of paralysis, when, on his recovery he associated his eldest son George in his business, to which, however, he continued to attend until the period of the fatal attack of the same disease, of which he expired, after five days' illness, on the 12th of June, 1861. His remains were interred at the City of London Cemetery, Ilford, in a spot which he had selected some months previously.

A bare recital of any man's works can give but an inadequate idea of his professional talents, and leaves untouched his character, and other attainments. But it is rather by these, and by his personal qualities, that he has endeared himself to his friends. It is admitted by all who knew Mr. Aitchison, that the works he executed conveyed only an imperfect notion of his powers, as by adverse circumstances, he was unable to display or to exercise the skill and talent he possessed, except in subordinate positions, until he had arrived at an age when success is scarcely sought and but little cared for. He belonged to the race of architects, now nearly extinct, who appeared to have taken the description of Vitruvius as a model, and were determined to arrive at an equality of excellence in every branch of their profession, and who ridiculed the idea of attaining celebrity in one part of their profession at the expense of ignorance in the other, and who were consequently outstripped in the race by others who carried less weight. He was not only excellent at arrangement and construction, but was one of the most beautiful draughtsmen of his day. He was also a first-rate surveyor, with skill in measuring, and with knowledge of the value of artificers' work; he was likewise a good land-surveyor, and he thoroughly understood the legal part of his profession. His industry, rapidity, exactness, contempt of money, and capability of sustaining long-continued mental and bodily fatigue, were remarkable. As an instance, it may be mentioned, that he could in one day make up the fair abstracts of the accounts of Greenwich Hospital, which occupied two of the best and hardest working clerks to copy in the same time. The beauty of his drawings attracted the attention of Sir John Soane and of Mr. John Shaw. At one period he worked for twenty hours a day for three weeks, only taking two hours' sleep daily. The soundness of his judgment, his determination and energy, his fearlessness and the tenderness of his heart, and his integrity, were apparent to all who knew him. He was a keen sportsman, excelled in athletic exercises, and was a tolerable musician. A close observer of nature, he knew the habits of all the birds and animals about the country, and the name of every indigenous plant. He was acquainted with the best English and foreign literature; but his favourite reading was travels, and as he traced the route on the map, and read the adventures, he often regretted that he had been denied the pleasure of exploring some wild and unknown land. He had during his life a large circle of friends amongst men distinguished in the arts and sciences, by whom his loss was sincerely lamented.

MR. JAMES BRAIDWOOD, son of a builder in Edinburgh, was born in that city in the year 1800, and received his education partly at the High School, then under the Rectorship of Professor Pillans, and partly from private masters, from whom he acquired the various branches of knowledge necessary for the business of a surveyor and builder. At the age of twenty-three, he became the superintendent of the City fire-engines; and within three weeks after receiving this appointment a series of fires, called the Great Fire of Edinburgh, took place in the High Street, which destroyed some of the loftiest and most picturesque buildings. These fires burnt for several days, and rendered between four and five hundred families houseless; while ten individuals were killed on the spot, or subsequently died from injuries they had received. Such an introduction to the profession of which he subsequently became the master, opened the eyes of young Braidwood to the importance of his new calling; and thenceforth his best exertions were devoted to the noble object of preserving the lives and property of his fellow-creatures from the ravages of fire. On that occasion the want of efficient fire-engines, and of unity of management on the part of those to whom the existing engines belonged, became alarmingly conspicuous, and the result was the co-operation of the city authorities and of the insurance companies, in forming the Edinburgh Fire Brigade, an institution which, organised and developed by Mr. Braidwood, became the model for all similar establishments in this country. The two great principles which he then contended for were the training of firemen, and combating a fire inside the building, instead of projecting the water from the street. He argued that engines could not be managed with any general prospect of success, unless the men were properly trained and prepared for the duty which was expected from them. Also, as he said, "the great point to which everything ought to be made subservient is, that the water on its discharge from the director should actually strike the burning material. This cannot be too often, or be too anxiously, inculcated on every one connected with a fire-engine establishment. Every other method, not having this for its grand object, will, in nine cases out of ten, utterly fail; and upon the degree of attention paid to this point, depends almost entirely the question, as to the amount of damage the fire will occasion." The Edinburgh 'Mercury,' of 14th August, 1828, bore testimony to the successful application of these principles. After referring to the excellent footing on which the fire establishment had been placed, it stated that now there were no serious fires in Edinburgh; for when a fire broke out, and they were not less frequent than formerly, it was at once checked. It was observed, "Not only is the apparatus constructed on the best possible principles, but the whole system of operations has been changed. The public, however, do not see the same bustle, or hear the same noise as formerly; and hence they seem erroneously to conclude, that there is nothing done. The fact is, the spectator sees the preparation for action made, but he sees no more. Where the strength of the men and the supply of water used to be wasted, by being thrown against windows, walls, and roofs, the firemen now seek out the spot where the danger lies, and creeping on hands and feet into a chamber full of flame, or smoke, often at the hazard of suffocation, discover the exact seat of danger; and, by bringing the water in contact with it, obtain immediate mastery over the powerful element with which they have to contend. In this daring and dangerous work men have occasionally fainted from heat, or dropt down from want of respiration, in which cases the next person at hand is always ready to assist his companion, and to release him from his service of danger."

In 1829, Mr. Braidwood forwarded a description of his chain ladder fire-escape to the Society of Arts, London, for which he received the large Silver Medal,[1] accompanied by a request that he would "give a complete account of his mode of drilling firemen, and combining the use of fire-escapes with the ordinary fire-engine service." The response to this was the publication, in 1830, of his work "On the construction of Fire-engines and Apparatus, the training of Firemen, and the method of proceeding in cases of Fire," illustrated by drawings from his own hand, and embodying the result of his Edinburgh experience. The following extract, from one of the numerous reviews of this book, will give an idea of the estimation in which the Author was then held:—"The Edinburgh Fire-engine Establishment is now all but perfect. A unity of system has been accomplished, and a corps of firemen mustered, who, in point of physical vigour and moral intrepidity, are all entitled to be denominated chosen men. At the head of this band stands Mr. Braidwood, the Author of this Treatise, an individual who has on several occasions given abundant evidence of promptitude in extremity, and a noble contempt of personal danger, and whose enthusiasm, in what we may call his profession, could not have been more strikingly exemplified than by his illustrating it in the manner we now see before us. It is the only book we are acquainted with that treats of the systematic training of firemen; and from the perspicuity of its detail, it must necessarily become the manual of all such institutions, and ought to find a place in every insurance office in the United Kingdom."

With respect to the state of London, as regarded protection from fire previous to the publication of this work, it should be remarked that, after the Great Fire of London, in 1666, various Acts of Parliament were passed referring to this matter. One in particular, in 1774, enacted that every parish within the Bills of Mortality should keep two fire-engines with their appurtenances; and as there were at that time about one hundred and fifty parishes, this would have given three hundred fire-engines for the protection of London. Before this Act was passed, several of the insurance companies kept fire-engines. Others aftewards followed their example, and the parish engines were allowed in a great measure to fall into disuse, except in so far as to evade the penalties of the statute. Several gentlemen connected with the insurance companies had tried, at various times, to amalgamate their whole force, and at last, stimulated by the success of Mr. Braidwood, in Edinburgh, this was accomplished. On the 1st January, 1833, Mr. Ford, of the Sun Fire Office, induced seven other companies to join in an association of fire-engines and firemen. The principles of this arrangement were, that all names, badges, &c., of the different offices should be given up, and the association be styled the London Fire-engine Establishment; that the expenses should be defrayed in proportion to the business done by each office in London, a minimum rate being fixed; and that a committee of management be formed of one member from each company contributing to the support of the brigade. This committee was fortunate in securing, at the outset, the services of Mr. Braidwood, as superintendent; a measure that contributed more than anything else to the success, growth, and prosperity of the infant establishment. On accepting his resignation, the Edinburgh Fire-engine Committee presented him with a gold watch and a vote of thanks, "for the singularly indefatigable manner in which he had discharged the duties of his important office, not merely by his extraordinary exertions on occasions of emergency, but for the care and attention he had bestowed on the training of the firemen, whereby the establishment had been brought to its present high state of efficiency." He had previously received from the men under him a handsome silver cup, bearing the following inscription:—"Presented to Mr. James Braidwood, by the City of Edinburgh Firemen, as a token of their admiration of him as their leader, and of deep respect for him as a gentleman."

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[1] *Vide* Transactions of the Society of Arts for the Year 1829. Vol. xlviii. Part i. p. 146.

In organising the London Fire-engine Establishment, he had to overcome the prejudices of the old firemen and their dislike to innovation. In this he succeeded admirably, and also in gaining the esteem and respect of the public, so that no body of men were more popular than the firemen of the London Brigade. The system of attacking the fire inside the building was now fully developed, and instead of standing on the pavement, and vying with each other as to which engine would shoot the water highest, the men went inside, combating the fire at its source. Nor was this done recklessly, as with all his fearlessness and intrepidity, safety of human life had Mr. Braidwood's first attention. How successful he was in this may be gathered from the fact that, notwithstanding the extremely hazardous nature of their occupation, only eleven of his men lost their lives by casualties during the twenty-eight years that he was at their head. Those insurance companies which at first held aloof soon saw the benefits of the undertaking, and in course of time nearly all gave up their separate establishments and joined the brigade.

As the means of extinguishing fires in London have, since the Tooley Street catastrophe, excited much public attention, and is expected to become the subject of legislation, a short description of the London Fire Brigade, by its late superintendent, cannot fail to be interesting. Replying to inquiries from Dresden, on the 23rd January, 1861, on the London fire extinguishing arrangements, he writes:—"The brigade now consists of one superintendent, four foremen, each being appointed to a district consisting of a fourth part of London, which he never leaves except on some very pressing emergency, and who, in the absence of the superintendent, has the sole command of all engines, or firemen, within, or who may come within, his district; twelve engineers, ten sub-engineers, forty-seven senior firemen, and forty-three junior firemen, in all one hundred and seventeen individuals. In addition there are fifteen drivers and thirty-seven horses, all living at the several stations, and ready when required. There is also a supplementary force of four extra firemen, four drivers, and eight horses living at the stations, pursuing their usual avocations, and only paid by the Committee when required. The mechanical appliances consist of twenty-seven large engines drawn by horses, eight small engines drawn by hand, two floating-engines worked by steam, one of 40 HP. and the other of 80 HP., one land steam fire-engine, and twenty-eight hand-pumps, one of the latter being carried on each engine. When an engine is sent to a fire, only four firemen and one driver accompany it. The levers are worked by the bystanders, who are paid one shilling for the first hour, and sixpence for each succeeding hour, besides refreshments. Upwards of six hundred assistants have been thus employed at one time. The principal protection of London against fire is entirely voluntary on the part of the insurance companies, to whom the above establishment belongs, there being no law in any shape whatever to control or sustain the brigade; and with the exception of some fifteen or twenty, the parish-engines are comparatively useless at a serious fire. It must not be omitted, that the greatest possible assistance is given to the firemen by the police, of whom there are about seven thousand, in keeping back the crowd, &c. The fire-offices look upon the whole as a matter of private business, so that the brigade is proportioned quite as much to the amount which the offices think it prudent to spend as to the size of the place. Paris, which is not half the size of London, and the buildings of which are much more substantial, has upwards of eight hundred firemen." With his usual abnegation of self, he concludes as follows:—"It appears to me, that any success which the brigade may have attained depends, in a great measure, on the liberal pay given, by which the best men for the purpose can be obtained, the favourable view in which the brigade is regarded by the public, and the willing and able assistance given by a numerous and perhaps the best police in existence."

Mr. Braidwood brought what is now called the "London Fire Brigade fire-engine" to its present efficient condition. While in Edinburgh he recommended a smaller-sized machine, but solely for the reason that he did not at that time see the practicability of increasing the power without increasing the weight, his object being to convey the engine with men and 'materiel' by a pair of horses rapidly to a fire. In his endeavours to do away with all unnecessary weight in the construction of fire-engines, he was ably seconded by Mr. Tilley, of the Blackfriars Road; so that eventually a fire-engine, to be worked by twenty-eight men, mounted on springs, &c., and fitted to carry men and implements, was produced, weighing 18 cwt. He also applied the ordinary military scaling-ladders for fire brigade purposes, two being carried with each engine, and he recommended several of these ladders placed on a two-wheeled carriage as a convenient fire-escape. In 1841, he induced the Admiralty to adopt hose-reels in the various dockyards, these implements having been previously successfully applied in New York. In 1848, he introduced the hand-pump, as an auxiliary to the ordinary fire-engine. He had frequently found it difficult to extinguish slight fires without damaging much property by water, and this little instrument, worked by one man, often saves the necessity for putting a large engine to work, and causes one bucket of water to be of more use than a dozen thrown about in the ordinary way. This useful machine, for which he sought no patent, has been extensively imitated.

He soon saw the importance of making provision for fire in the waterside property of London; and shortly after his appointment, he designed and had constructed two powerful floating fire-engines for the purpose. The largest of these was worked by one hundred and twenty men, and, compared with the land fire-engines, was a very powerful machine. In 1852 he made still further progress, and persuaded his Committee to alter one of the floating fire-engines so as to be worked by steam-power instead of by manual labour. This experiment was so successful that, in 1855, an entirely new self-propelling floating steam fire-engine was constructed. Both of these engines have been of great use at numerous large fires. In 1860 he further imbued his employers with so much of his progressive spirit, as to obtain a land steam fire-engine, and he lived long enough to prove the great advantage of such machines for the extinction of fires in London.

As early as 1841, the Government began to profit by his experience, the Lords of the Admiralty having in that year consulted him on the subject of floating fire-engines for the various dockyards. These were eventually constructed, from his designs and under his superintendence. In the following year he inspected all the dockyards, and reported fully on each, with regard to both floating and land fire-engines, the supply of water, the alterations of buildings to prevent spread of fire, and the proper care required in dangerous trades. From this time, although not holding any appointment, he acted as Government consulting Engineer on all questions relating to fire prevention and extinction, and he advised, from time to time, the precautions to be taken for the protection of the royal palaces and various other public buildings: this position enabled him, not without a great deal of opposition, to induce the Government to adopt in all its departments a uniform size of hose-coupling. This is the one which he introduced in Edinburgh, now known as the London Fire Brigade coupling, and is in almost universal use; and its application has been found, comparatively, of as much utility for fire brigade purposes, as the adoption of the Whitworth gauges of screw-bolts for mechanical engineering.

Although so fully occupied, he never refused advice on professional matters to all who sought it. The various Dock Companies, Public Institutions, Country Fire Brigades, private firms, &c., benefited largely by his experience. The numerous inquiries from foreign countries and the colonies, with regard to the best means of extinguishing fires, also made great inroads on his time. In 1833 he became an Associate of the Institution of Civil Engineers, to which, in 1844, he contributed a valuable Paper "On the means of rendering large supplies of Water available in case of Fire, &c.,"[1] for which he was awarded a Telford Medal; and in 1849 a second Paper, "On Fire-proof Buildings."[2] In 1856, a Paper on "Fires—the best means of preventing and arresting them; with a few words on Fire-proof Structures,"[3] was read by him before the Society of Arts.

He took great interest in the passing of Acts of Parliament for regulating buildings in the metropolis, was consulted by the framers of these Acts, and used his utmost influence to prevent the endangering a whole neighbourhood, by the erection of monster warehouses for private profit. He strongly contended for the principle of dividing buildings by party-walls carried through the roof, and restricting these divisions to a moderate cubic content. Writing to Lord Seymour, Commissioner of Woods and Forests, on the 28th June 1851, he said, "that no preparations for contending with such fires will give anything like the security that judicious arrangements in the size and construction of buildings will do." The wise provisions introduced, through his instrumentality, into these Acts of Parliament, were continually being evaded, and clusters of warehouses quickly rose which he saw would, if on fire, defy all his means of extinction. In a letter to Sir W. Molesworth, First Commissioner of Public Works, dated 10th February, 1854, on the subject of a proposed warehouse in Tooley Street, he wrote,

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[1] *Vide* Minutes of Proceedings Inst. C.E., vol. iii., p. 309.
[2] Ibid., vol. viii., p. 141.
[3] *Vide* Journal of the Society of Arts, vol. iv., p. 413.

"The whole building, if once fairly on fire in one floor, will become such a mass of fire, that there is now no power in London capable of extinguishing it, or even of restraining its ravages on every side, and on three sides it will be surrounded by property of immense value." How literally this was realised, and at what cost, was shown by the great warehouse fire of Tooley Street, on the 22nd June, 1861, at which Mr. Braidwood lost his life! The distressing circumstances are so well known as not to require repetition. He died as he had lived, doing his duty, the last act of which was attending to the safety of his men.

Few men ever received such a public recognition of esteem and affection as was accorded to Mr. Braidwood at his funeral, the long line of thoroughfares through which the procession passed, on its way to the Abney Park Cemetery, being crowded with people, while a vast number of police and others attended as mourners. To show the universal, as well as national, esteem in which he was held, two extracts may be given from the numerous letters of condolence addressed to his bereaved family, from all parts of the world. Mr. G. H. Allen, Secretary to the Boston (America) Fire Department, writes:—"It gives me pleasure to unite with the Board in testimony to the extreme kindness of Mr. Braidwood in the conduct of our correspondence, whereby we have been greatly benefited and received extensive information. Allow me also to extend our sympathy to those who have lost one who will ever be remembered as standing at the head of the most valued arm of the Government, and one that you can hardly expect to be replaced, except by years of experience and great natural ability." Mr. T. J. Bown, Superintendent of the Sydney (Australia) Fire Brigade, in a letter dated 22nd August, 1861, says, "On receipt of the sad news our large fire-bell was tolled, the British ensign hoisted half-mast high, and crape attached to the firemen's uniform, as a token of respect for one of the noblest and most self-denying men that ever lived, who spent and lost his life in the service of his fellow-creatures."

MR. CHARLES FREDERICK CHEFFINS was born in London on the 10th of September, 1807. His father had for many years acted as official manager to the New River Waterworks Company, in superintending the boring by machinery of the wooden pipes then in use for the supply of water to the metropolis. Having been so fortunate as to obtain a presentation to Christ's Hospital, young Cheffins was, in July, 1815, admitted as a scholar into that institution, where he remained till the year 1822, prosecuting his studies with a fair amount of diligence, and obtaining several gold medals for his proficiency in arithmetic and mathematics. During the whole of his after-life, he entertained the most grateful remembrance of the advantages he derived from that valuable foundation. On the completion of his education, he was articled to Messrs. Newton and Son, Patent Agents and Mechanical Draughtsmen; and in their employ he obtained some excellent practice, in making drawings from specifications and from models of machinery, which proved very useful to him in his after-career, and aided in giving him that intimate knowledge of his profession which he was admitted to possess. With Messrs. Newton and Son he remained some time after the expiration of his pupilage. About the year 1830, he obtained an engagement under Captain John Ericson, to assist in making the drawings for the 'Novelty' locomotive engine, then about to be constructed by Messrs. Braithwaite and Ericson, for competition with the 'Rocket' and other engines on the Manchester and Liverpool Railway. The result of the competition, as is well known, proved adverse to the 'Novelty,' on account of the failure of the blast apparatus. Mr. Cheffins was present at the opening of the Liverpool and Manchester Railway, and remained some time longer with Captain Ericson, making drawings for other inventions, amongst which was a steam fire-engine and a caloric engine—machines which excited considerable attention at the period, and the former of which has since come into general use. In these matters Mr. Cheffins' practical knowledge of machinery rendered him a very valuable assistant in the preparation of the designs. In the year 1831 he was introduced to the late Mr. George Stephenson, by the late Mr. Padley, who was that gentleman's oldest associate and surveyor. After the successful opening of the Liverpool and Manchester Railway, numerous other schemes were immediately started, in which the great Engineer occupied a prominent position. Mr. Cheffins' first occupation under Mr. Stephenson was in the preparation of the plans and sections of the projected Grand Junction Railway, which had for its object the connection of the towns of Birmingham and Liverpool; and it was whilst engaged upon this work, that his persevering industry was noticed by those with whom he was brought into contact; amongst whom may be mentioned the late Mr. Joseph Locke, M.P., Mr. Swanwick, Mr. Gooch, and many others, who have since become eminent in the Engineering profession. On the completion of the parliamentary deposits for the Grand Junction Railway, Mr. Cheffins terminated his engagement with Mr. Stephenson, and, foreseeing that railway schemes were only then in their infancy, and that much work might be anticipated, by devoting himself exclusively to the surveying department of the profession, he established himself in London, and commenced business on his own account. He had the good fortune to retain the support and patronage of all those with whom he had been previously associated, besides adding many other names to his list of friends. The late Mr. Robert Stephenson, M.P., was among the latter, and under his direction and superintendence, he prepared many of the designs for the construction of the bridges on the London and Birmingham Railway, and was also engaged by him on various other matters. This kind friendship and support only ceased with Mr. Robert Stephenson's death, and Mr. Cheffins ever entertained a most lively regard for the man to whom his success in life might be fairly attributed. It is unnecessary here to enter into the detail of the numerous projects with which Mr. Cheffins was associated during the many years he continued in the exercise of his professional career. The London and Blackwall, the Great Eastern (then the Eastern Counties), the Trent Valley, and the North Staffordshire Railways, are a few of those which he lived to see brought to a successful completion, though in their course through both Houses of Parliament they had to sustain the heavy and determined opposition of other powerful companies and of large landed proprietors. As a testimony of the esteem in which his services were held, during the many years he was engaged in these and other matters, a valuable service of plate was presented to him in the year 1846, the subscription being headed by the leading Engineers of the day. This token of regard has been handed down to his family to be kept by them as an heir-loom. The last great scheme in which he was employed was the projected Great Eastern Northern Junction Railway Bill of 1860, (known familiarly as the 'Coal line,') which his good friend Mr. George Parker Bidder had placed in his hands, and in which he took a deep interest; but death cut him short whilst in the active discharge of his duties. He died from an internal injury on the 22nd of October, 1860, after only a few hours' illness, leaving his son (with whom he had been associated in partnership for some years) to complete that which he had with so much zeal only a month, or two, previously commenced.

His death, at the early age of fifty-four years, caused profound regret to all those with whom he had been connected for so many years, as also to those of his assistants, who had served under him in the numerous parliamentary campaigns in which he had been engaged—and to many of whom he had shown much kindness in recommending them to posts of trust and responsibility on the Indian railways. The career of Mr. Cheffins presents no feature of extraordinary interest save the example of the persevering industry of an honest man—one of those whose lot it has been to carry out the plans of others, without endeavouring to attribute to himself the merit appertaining to those who employed him. He was elected an Associate of the Institution of Civil Engineers in the year 1848, and he never ceased to take great interest in all the proceedings.

Mr. OCTAVIUS COCKAYNE served a regular period of pupilage under Mr. Dodd, as a Surveyor; he then received an engagement as an Assistant Engineer under Mr. Birkinshaw (M. Inst. C.E.), on the Hull and Bridlington, and on the York and Market Weighton Railways, and on some of the branches of the North Midland Line, where he remained for nearly four years; he then occupied himself in getting up Parliamentary plans and surveys. On the dearth of employment, consequent on the simultaneous completion of so many lines, he turned his attention to the traffic management and rating of railways and to commercial pursuits, which led him to Canada, where he died in the month of September 1861, at the age of thirty-five, deeply regretted by all who knew the uprightness of his character, and the kindliness of his heart.

Mr. Cockayne joined the Institution as an Associate in the year 1855, but his pursuits precluded his taking any active part in the proceedings. Applications to the friends have failed in procuring materials for a fuller Memoir.

Mr. CHARLES COWPER, the second son of Professor Cowper, of King's College, London, (whose invention of the printing-machine, now in common use, is so well known,) was born on the 8th of August, 1821. After receiving his education at a private academy and at University College School, Mr. Charles Cowper was articled to Mr. W. Maugham, a practical and analytical chemist, and he subsequently studied under Dr. Faraday and Mr. Brande, whilst he simultaneously followed, to some extent, those mechanical pursuits to which his father and his brother were more particularly devoted.

In 1841 he became the practical and analytical chemist to Messrs. Chance Brothers and Co. at their extensive glassworks, near Birmingham, and made several useful improvements in the mixtures for coloured glass for horticultural purposes, of which the palm-house in Kew Gardens was one of the largest examples. He also improved the working of sulphuric acid chambers, obtaining a larger yield per pound of sulphur than had been usual. In 1848, he commenced business on his own account in London as a patent agent; and having profited by the opportunities he had of studying mechanical science and Engineering generally, he soon established a considerable reputation, both in reference to chemical and mechanical inventions; indeed, in the specifying of patents he was so careful, that not one of those drawn by him has ever been successfully contested. He was much respected by a wide circle of friends, for his amiable disposition, his uprightness of character, and great moral worth. He expired on the 23rd December, 1860, leaving a wife and family to lament a kind and affectionate husband and parent. He joined the Institution as an Associate in the year 1850, and took much interest in the proceedings, frequently attending the meetings and assisting in the discussions.

COLONEL ROBERT KEARSLEY DAWSON, C.B., of the Royal Engineers, the eldest son of Mr. Robert Dawson, of the Corps of Royal Military Surveyors and Draftsmen, was born in the year 1798. He joined the Royal Military Academy, at Woolwich, in 1812, and obtained his Commission in the Royal Engineers, in 1815.

After serving for a short time at Chatham, he was attached to the Trigonometrical branch of the Ordnance Survey of Great Britain, and was employed in Scotland under Major Colby, in conjunction with Captains Vetch and Robe, and his old college friend, Lieutenant Drummond. In the rugged Highlands, in that northern portion of the island, the trigonometrical operations—of which the stations were of necessity always on the highest summits—involved, in the selection of the most suitable points, an amount of toilsome marching which can be appreciated only by those who have had experience of it. Unlike the hardy hunter of the red deer, in search of manly sport, and healthy recreation and exercise, the station hunter has no comfortable home to receive him at night. He must take up his quarters in the nearest shelter, and resume his walk at earliest dawn. In General Portlock's Memoir of the late Major-General Colby,[1] some of the adventures and the enjoyments of the mountain camp are graphically described, in a letter from Colonel Dawson; and such was his duty in the early period of his connection with the Survey.

In 1822, the operations for the triangulation of Scotland were suspended, and Lieutenant Dawson was stationed at the Tower of London, in local charge, under Captain Mudge, of the Map Office. In that duty he was eminently useful, for among his other professional acquirements, Lieutenant Dawson was an artist of considerable capacity:—and to his taste, in conjunction with the skill of his no less accomplished father, the great perfection attained in the delineation of ground on the English Ordnance Maps, is mainly to be attributed. Lieutenant Dawson, at this time, also shared largely in the scientific pursuits and occupations of his friend Drummond, who was likewise retained in London during the interval between the suspension of the Scotch, and the commencement of the Irish survey. Here he continued to be employed for several years, and for a time his career was intimately connected with that of Drummond. In 1830, the outline survey of the North of Ireland had become sufficiently advanced to enable the General Map on the smaller scale to be commenced, and for that duty Lieutenant Dawson's experience on the English survey rendered him pre-eminently fit. He was accordingly selected for it by Colonel Colby, and removed to Ireland, being stationed first at Londonderry, and afterwards at Ballymoney in the county of Antrim. On this duty he remained until 1836. During this period he was withdrawn to England for a time in 1831, at the instance of his friend Drummond, to be employed in conjunction with him on the Parliamentary Reform Bill, where Lieutenant Dawson's topographical knowledge became conspicuous, in the arrangements for rapidly producing plans of all the boroughs, and the correct delineation of the boundaries within which the elective franchise was to be exercised, as well as those to be used for the divisions of counties. Again, in 1835, he was called upon to take a similar part in the measures for Municipal Reform in the English boroughs, then contemplated by the Government, and proceeded to London for that purpose. He resumed his duty in Ireland for a short time, and laboured zealously: and as before, not only in that branch of the Survey, but in the collection of statistical and antiquarian materials for the General and Descriptive Memoir, which it was then contemplated to publish in connection with the maps. He was not destined, however, to remain in Ireland; for in 1836, the Commutation of Tithe was rendered general in England, and for that purpose maps on a much larger scale than then existed, were required. To the charge of a department for that purpose Lieutenant Dawson was called, and he was appointed an Assistant Commissioner, in England, under the Tithe Act of that year. Lieutenant Dawson speedily perceived that an opportunity was thus afforded for producing a Cadastral Survey, and he drew up an admirable code of instructions for the production of the separate Parish Maps on an uniform scale and system, devising at the same time a means of connecting and combining them. This is explained in a Paper laid before Parliament, and printed in the Session of 1837.[1] The Tithe Maps, thus prepared, form a most valuable collection, consisting of about twelve thousand Parish Maps, which are still largely used for all purposes connected with land. To this bold experiment, and to the success which attended it, it is not too much to say, that the country owes the ultimate establishment of the large scale on which the Ordnance

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[1] *Vide* "Papers on Subjects connected with the Duties of the Corps of Royal Engineers," vol. iii. New Series. 8vo. London, 1853, p. liv.

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[1] *Vide* "Survey of Lands (Tithe Act). Copy of Papers respecting the proposed Survey of Lands under the Tithe Act, 10th March, 1837." Vol. 41, Parliamentary Papers, Session 1837, page 333.

Survey, in the outline maps, is now so admirably carried into effect, under the present able conductor of the Survey, Colonel Sir Henry James, C.B., F.R.S. (Assoc. Inst., C.E.) On the increased scale, and the uses to which it was applied, and to which it became more and more applicable, rapidly followed the discussion on the introduction of the decimal, or proportionate scale, now adopted; and the controversy on the relative advantages of contouring, and of other modes of indicating the heights and undulations of ground. The reports and evidence on these subjects are embodied in a Parliamentary Volume;[1] and the (perhaps, too great) heat with which the discussions were conducted, like the 'Battle of the Gauges' evinces at once the ardour of the advocates of the several systems, and the real importance of the subject to the practical Engineer. To the Tithe Commission, the Copyhold and Enclosure Commissions were subsequently added, and on that combined duty Colonel Dawson continued to be employed in the same capacity as before.

In addition to the official duties more immediately intrusted to him, Colonel Dawson became, from his acknowledged ability and integrity, the established referee of the Government and the Treasury on Colonial Surveys,[2] and indeed on all subjects in which Topographical knowledge and work were required. He was also appointed a member of the first Metropolitan Sewers Commission. His judgment became more and more matured; his knowledge increased, and his powers of labour never flagged. Though of delicate constitution originally, he continued to enjoy as good health as constant office duty usually affords: until a sharp and unexpected illness, from congestion of the lungs, hurried him rapidly to the grave, in March, 1861, at the age of sixty-two years.

He remained on the active list of the corps of Royal Engineers till the rules of the service compelled him to retire. He attained by successive steps the rank of Colonel, and received the distinction of Companion of the Bath, for his service in a civil capacity. In the midst of pressing official occupation, he was ever ready to assist, with his purse and advice, any deserving person; and his charitable and kind disposition caused him to be generally beloved and admired. He had been an Associate of the Institution exactly twenty-three years on the day of his death, and occasionally attended the meetings, when he felt interested in the subject under discussion.

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[1] *Vide* "Ordnance Maps. Correspondence respecting the Scale for the Ordnance Survey; and upon Contouring and Hill Delineation." With Maps. 1854, and Vol. 41, Parliamentary Papers, Session 1854, page 187.

[2] *Vide* "Report on Surveying considered with reference to New Zealand, and applicable to the Colonies generally, Addressed to the Right Hon. Lord John Russell, 22nd Dec., 1840." London: Clowes and Sons, 1840.

MR. HENRY ALCOCK FLETCHER was born on the 16th January, 1820, at Ripley, in the county of Derby, where his family had been settled for some generations. After receiving a useful education he was, at an early age, put in training for the acquisition of that acquaintance with the conduct of large commercial enterprises, which he afterwards turned to so good an account. For many years he was employed in the establishment of Messrs. Euclid Shaw and Sons, carriers in Bath, under whom he became thoroughly conversant with the management of all the details of their extensive carrying trade. He was afterwards employed in the traffic department of the Midland Railway, and subsequently, for a short time, in the establishment of Messrs. Pickford and Co. His next appointment was that of assistant traffic-manager to the London and South-Western Railway Company; during the last year of his connection with which he had the entire management of the Dorchester Line. Subsequently he was for several years connected, as traffic-manager, with some of the principal lines of railway in Ireland, where the value of his services met with marked recognition, and where he acquired many lasting connections. In consequence of the reputation he there succeeded in earning, he was in 1855 selected, from a large number of candidates, to fill the important post of traffic-manager, in India, for the Madras Railway Company. In this situation Mr. Fletcher did not disappoint the expectations raised by his previous character, so that after discharging with great credit to himself for several years the duties of the office intrusted to him, he was, in 1860, appointed by the Directors to fill the position of general agent and manager in India. This appointment Mr. Fletcher held up to the time of his death, which occurred in June, 1861, in the Red Sea, on his passage home, he having at length reluctantly yielded to the pressing necessity of endeavouring to recruit his health, by a temporary change from the Indian climate, from the effects of which he had latterly begun to suffer severely. Mr. Fletcher was particularly distinguished for the determined energy with which he pursued and carried out any object which he had once fixed upon as desirable. In this his views were seldom limited by the precise boundaries of a single department, every matter being regarded by him in its most general point of view, with reference to the interests of his employers. Thus, while in charge of the traffic department of the Madras Railway, he found time to take the chief part, in co-operation with other officers of the Company, in reorganising, and placing on a sound footing, the transactions of the General Stores department, which, through unfortunate circumstances, had fallen into an unsatisfactory condition. At the same time his experience and skill, in the arrangement of carrying operations, were brought to bear with great advantage in aid of the Engineering department, by the establishment of a system for the transport of materials along the line, by which a centralised control was obtained, and the chances of raising prices by unconscious competition amongst the Company's officers at the various stations were eliminated.

Mr. Fletcher's exertions to promote the success of the enterprise in which he was concerned, extended even to matters having a less obvious connection with it. He was an active promoter, and indeed the originator of several projects, since carried into operation, for improving the means of transport in all parts of the country, from which trade might be expected to flow to the railway; and with this object, he took the chief part in the establishment of a line of coaches, on the English plan, between the great military station of Bangalore and the station nearest to it, a distance of eighty miles.

He was an active member of the Madras Chamber of Commerce, fully realising the importance of every measure calculated to develop the trade of that port, which is so intimately connected with the Madras Railway.

In private life, Mr. Fletcher was remarkable for his sociable and friendly disposition—for his unbounded hospitality—and for the interest he took in all public institutions of a useful, or charitable character. It may not be out of place to mention, that at the period of the outbreak of the Indian Mutinies, he took a very active part in the formation of the regiment of Madras Volunteer Guards, in which he, for some years, held a commission as Captain, and of which he was at the time of his decease the Major. His popularity amongst the officers and men of this corps was signalised at the time of his departure for England, when a subscription was entered into, for the purpose of presenting him with a sword, as a token of the esteem in which he was held. The unfortunate issue of the journey modified the carrying out of the intention, which took the form of the foundation of a scholarship in a charitable educational establishment of which he was a director—the presentation to which is for life placed in the hands of his widow. Mr. Fletcher was elected an Associate of the Institution of Civil Engineers in 1859.

Mr. LIONEL GISBORNE, M.A., &c., was born at St. Petersburg in the year 1823, where his father was British Consul General. His family had for several centuries been settled in Derbyshire, and members of it had frequently represented in Parliament both the county and the town of Derby. Mr. Lionel Gisborne received his education partly at St. Petersburg, and partly at Repton school, in Derbyshire, and he was also at the school of Monsieur Venel, at Geneva, where he acquired a familiarity with French and other European languages, which was of great service to him in after life. His education was completed at the University of Durham, where he devoted himself principally to Mathematics and Natural Philosophy, together with other branches of study to qualify him for the profession which he had already then selected. Although he unfortunately was seized with an illness, during the final examination, which prevented him from undertaking all the papers, he nevertheless took honours, and afterwards obtained a fellowship, and the diploma of a Civil Engineer.

He immediately commenced the exercise of the profession, and from the age of nineteen, when he quitted the University of Durham, until the day of his death, he was almost uninterruptedly engaged on Engineering works. He was for a short time employed upon the Ordnance Survey of England, and then proceeded to Ireland, in 1842, where he remained for ten years in the Government service; first under the Commissioners for the Improvement of the Navigation of the River Shannon, and afterwards under the Board of Public Works, on the Arterial Drainage of the Country. Lieutenant-General Sir Harry D. Jones, R.E., K.C.B., (then Colonel Jones,) was at that time Chairman of the Shannon Commission, and he afterwards became Chief Commissioner of Public Works in Ireland; in both positions he remained the stanch friend of Mr. Gisborne, of whose powers he entertained a high opinion.

The Shannon works upon which Mr. Gisborne was employed, were of considerable importance and magnitude, consisting principally of the deepening of the river, by excavation and dredging, the removal and rebuilding of bridges that cross the river at Athlone, being one of the principal structures of that kind; and during the execution of these works he acted as one of the resident Engineers, and had at the same time charge of the building of locks, weirs, river walls, wharves, and all works incidental to these operations; keeping them clear from water formed no inconsiderable item in the difficulties that had to be contended with in dealing with a river so liable as the Shannon to sudden and high floods. He had afterwards sole charge of extensive works on the Upper Shannon, including the renewal and deepening of the Loch Allen Canal, at the head of the river. These works were finally completed in 1851, and for the last two years he had charge of them as the Engineer in Chief.

Whilst he was still employed on the Shannon, he was appointed by the Board of Works as Engineer over several extensive Arterial Drainage districts situated in the Counties of Longford and Roscommon, most of which were completed by him previous to his leaving Ireland in 1852.

He also took an active part in the Relief Works for the employment of the labouring poor during the famine in 1846-47. He did not limit himself to fulfilling his duties as an Engineer, but in his private capacity, and with the assistance of his English friends and relations, he did much to relieve the urgent necessities of the starving population, by the establishment of soup kitchens and the distribution of clothes. He had as many as four thousand men employed under him at a time, during his engagement on the Shannon Works. He also served for a short time under Mr. Charles Vignoles (M. Inst. C.E.) in making surveys and preparing plans for the Limerick and Waterford Railway.

In all these employments, and especially in the Relief Works, he had many opportunities of displaying that comprehensiveness of mind, promptitude of decision in emergencies, and power of influencing and attaching those associated with him, for which he was distinguished in after life. One of his principal characteristics was the anxiety he always evinced for advancing the younger members of the profession who had at any time co-operated with him in any works, and this he had many opportunities of doing during his career;—especially when at the request of the late East India Company in 1855 he formed a staff of Engineers for the Government Public Works in India. This corps was the origin of the present Public Works Department in that country.

In 1852, the works he was engaged on in Ireland being nearly completed, he removed to London, where he continued to practise as an Engineer up to the period of his death. The experience he had gained in Ireland naturally induced his attention, in the first instance, to works of a similar nature to those on the Shannon. In consequence of representations made by Dr. Cullen, as to the nature of the country across the Isthmus of Darien, between Port Escoses, on the Atlantic side, and Darien Harbour, on the Pacific, Sir Charles Fox (M. Inst. C.E.,) in 1852, requested Mr. Gisborne to undertake an expedition, to ascertain, as well as circumstances would permit, the feasibility of constructing a ship canal, in that locality, to unite the two oceans. He proceeded to the Isthmus, in April of that year, accompanied by Mr. Henry C. Forde, (M. Inst. C.E.,) who had been throughout associated with him as an Engineer in Ireland. Unfortunately they arrived on the Isthmus during the rainy season, and were prevented by the combined effect of weather, illness, and the hostility of the Indians,—amongst whom they ran great risks, and whose prisoners they were for a short time,—from making any effectual survey. It was considered, however, that in conjunction with Dr. Cullen's statements, sufficient information had been collected to justify a second expedition on a more enlarged scale, which was consequently organized in 1854, the Governments of England, France, the United States and New Granada, sending ships of war to both sides of the Isthmus to protect and assist the surveying expedition. This time Mr. Gisborne took out with him a regular staff of Engineers. H. M. Government appointed Lieutenant St. John, R. E. to accompany them in their surveys, and to report to the Government. The United States Government also sent out a surveying expedition under Lieutenant Strain, U. S. N. The result of these surveys satisfied Mr. Gisborne, that the construction of a ship canal was impracticable. This conclusion was only arrived at after he and Lieutenant St. John had crossed from sea to sea, and after several series of instrumental levellings had been taken across the summit level, as far as it could be ascertained, considering the dense nature of the tropical forest. Captain Prévost, R. N. of H. M. S. 'Virago,' had attempted to penetrate the country from the Pacific side with a party of sailors immediately before Mr. Gisborne's last expedition. He failed, however, in crossing the Isthmus, and in this attempt, four of his sailors were murdered by the natives. Mr. Gisborne refused to receive any remuneration for his services in these expeditions. The summary of the report of Mr. Gisborne on the last expedition is published in the Journal of the Royal Geographical Society, illustrated by a map of the locality.[1] He also published two statements of the proceedings in the Isthmus.[2]

Mr. Gisborne was then employed to report upon a system of Railways for Switzerland. He also made preliminary surveys and reports upon several lines of Railway in Italy, and in Russia, some of which are now completed and others are in progress.

In Russia he also made a report upon the means for improving the Navigation of the River Dnieper, and prepared preliminary plans for executing the work. For the Swedish Government he made detailed surveys and plans for the Southern System of Railways which are now being gradually carried out.

In 1852, Mr. Gisborne brought forward a scheme for the Embankment of the River Thames. His proposed plan consisted of building quay walls on each side of the river from Lambeth to London Bridge, and thereby making the river of nearly uniform width between those points. Behind these walls a solid embankment was proposed, between which and the existing wharfs there would be floating basins with tidal entrances to accommodate the existing traffic. Upon the Embankment on the Middlesex side, a road, a railway, and a covered esplanade were provided for, as well as extensive building sites for shops and stores. The object in thus utilising the Embankment, was with a view to insure a commercial return. For the opposite side he designed a broad road with a reservation of but few building sites, and provision was made under both Embankments for a low level sewer, in conjunction with the Great Drainage plan for London, now being carried out by the Metropolitan Board of Works. These plans were brought under the notice of Lord Palmerston and Sir William Molesworth in 1853, and subsequently before the various Parliamentary Committees which sat upon this subject, as also before the Metropolitan Board of Works, where they were carefully considered and were favourably reported upon, and undoubtedly they contributed to the solution now arrived at upon the question. Mr. Gisborne also made alternative plans for carrying out the Embankment under the different circumstances which would arise, in case they were executed at the public expense instead of by private enterprise; and he continued actively to occupy himself on this subject up to the date of his death.

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[1] *Vide* "Journal of Royal Geographical Society," vol. xxvii., page 191.

[2] *Vide* "The Isthmus of Darien in 1852. Journal of the Expedition of Inquiry for the Junction of the Atlantic and Pacific Oceans." By L. Gisborne. 8vo., maps. London, 1833.

In the latter years of his life Mr. Gisborne was principally engaged in connection with the long submarine telegraphs which he projected to connect England with her Eastern possessions. Few submarine telegraphs, in any part of the world, have up to the present time proved permanently successful, although the cable laid between Malta and Alexandria in the autumn of 1861, the last line to which he was Engineer, gives fair promise of proving so. As far back as 1854 he projected a submarine telegraph to India. As a first step to this he made arrangements with the Ottoman Government for laying a submarine line between the Dardanelles and Alexandria. The cable was successfully laid, as far as the Island of Candia, in December 1858, and has since remained in perfect working order; but the attempts to complete the line across the deep water to Alexandria have failed. In 1855 he sent his brother, Mr. Francis Gisborne, to complete the arrangements, with the Ottoman and the Egyptian Governments, for establishing the Telegraph to India. The necessary powers for constructing the line across Egypt, and for establishing stations on the coasts of the Red Sea, reserving to the company complete control over the line of communication, having been obtained by him, the Red Sea and India Telegraph Company was formed, and Mr. Lionel Gisborne was appointed their Engineer. The cable was laid in 1859 and 1860 from Suez to Aden, and thence to Kurrachee, a distance of upwards of 3000 nautical miles, in six sections. The Suez-Aden line, of 1,360 miles, worked well for nine months without requiring repairs; the other portions of the line failed within a short time after submersion, and in consequence of the Company being unprepared to repair it, the line has hitherto remained inoperative, but exertions will be made to restore the communication.

Mr. Gisborne also projected lines to Australia viâ Rangoon and Singapore, to Java, and thence, viâ the Northern and Eastern coast of Australia, to Sydney. In furtherance of those plans he induced the Dutch Government to lay a line between Singapore and Batavia in 1859, a distance of six hundred nautical miles. This line has been subject to frequent interruptions through the fracture of the cable by anchors, but being in shallow water, it is easily repaired. He left behind him matured plans for the continuation of this line to Australia, which were brought under the notice of the several Australian Governments by Mr. F. Gisborne in 1860, and subsidies were voted to enable them to be carried out.

For two years before his death, he, in conjunction with his partner Mr. Henry C. Forde, was Engineer to Her Majesty's Government for their submarine telegraphs. Although the laying of the Malta-Alexandria cable was not completed till some months after his death, yet the manufacture of the cable had been finished and all the arrangements for the laying were made previous to that event. The merit also of the adoption of the perfect system of testing, which was for the first time introduced in the case of this cable and was carried out by Mr. C. W. Siemens (M. Inst. C.E.), may be claimed for Mr. L. Gisborne. The system of laying the cable in moderate depths and, as far as necessary, within sight of land, in order to fix its position, and with a view to its subsequent recovery for repairs, was first carried out in this case, and is due to his foresight. Other improvements, such as carrying out the cable in water-tight tanks, fitted on board the ships, to enable it to be continually tested under water, until the time for submersion, were likewise for the first time adopted in this instance, and they have greatly diminished the risk and uncertainty which have hitherto attended such undertakings. Mr. L. Gisborne was also Engineer to the French Government for the cable successfully laid between France and Algiers. It may be stated, with reference to long submarine lines, that no Engineer of his day was so successful in procuring the adoption of the routes he pointed out, in the face of rival routes influentially supported. This was particularly the case with reference to the telegraphs to India and to Australia. The practice of submarine telegraphy dates only from about 1851, and within the ten years which he devoted to it, no one of his day laboured harder in extending the system, or did more towards the attainment of success. He led an untiringly active life, and his wide views introduced him to undertakings of great magnitude and corresponding risk. He was very successful in gaining the adhesion of others to his plans, and the influence he exercised over all whom he approached was generally acknowledged. He particularly distinguished himself on the occasion of the wreck of the Steam Ship "Alma," in 1859, in the Red Sea, and by his exertions during several days, whilst the passengers remained on a coral reef near the island of Little Harnish, exposed to the heat of the sun, without shelter and almost without fresh water; services which were recognized by a complimentary address from his fellow-sufferers. The goodness of his heart and the excellence of his disposition were never better exemplified than on that occasion, when his best energies were devoted to the safety and comfort of the women and children. It is but justice also to state, that in all money matters, Mr. L. Gisborne was peculiarly generous and disinterested. His energy was untiring, and though he died at an age when many men only begin to be known, his name will undoubtedly live in the future, in connection with the branches of Engineering to which he devoted his attention.

He died on the eighth of January, 1861 at the early age of thirty-eight, after a short but very active career. He joined the Institution of Civil Engineers as an Associate in the year 1852, and when he was in London he evinced great interest in the proceedings of the Society.

MR. WILLIAM NEWTON was born in London, in the year 1786, and he was early inducted by his father into the practice of land surveying, levelling and mechanical drawing, branches of professional employment which had been exercised by his predecessors for two centuries back, in conjunction with the manufacture of globes "at y^{e} Globe and Sun, Chancery Lane, Fleet Street."

At an early age Mr. Newton evinced a desire to study Archæology and Heraldry, sciences which with Astronomy he cultivated with ardour in after life, and upon which he eventually published some works; he also gave lectures on those subjects before the "City Philosophical Society," of which Michael Faraday and other now well-known men were members. On the breaking up of that society, he joined the Society of Arts, of which he was for many years an active member.

His professional surveying engagements rendered him familiar with many out of the way and almost forgotten localities and sites of ancient buildings, and gave him a store of archæological knowledge which many years after he embodied in a "Map of London in the Olden Time," a work of great merit and infinite research.

His talent as a mechanical draughtsman was early recognized by his appointment to the profitable post of draughtsman to the several offices in which the specifications of patents were recorded, and this eventually led to his becoming a Patent Agent, a professional branch which he may be said to have created, and in the exercise of which he was very successful. His specifications were remarkable for their perspicuity and conciseness—qualities which had been previously little valued.

In the year 1820 he, at the solicitation of Mr. Sherwood, the Publisher, established and became the editor of the 'London Journal of Arts and Sciences,' a work which was commenced chiefly with the object of reporting upon all inventions recorded by letters patent. The difficulties of performing the duties of editor were, from the regulations of the Enrolment Offices, very great, but for some years they were satisfactorily combatted. The annually increasing number of Patents eventually, however, made it impossible to do more than to record the titles of all the Patents, and rendered necessary an arbitrary selection of subjects for description.

In the prosecution of his business, he visited all the seats of manufacture in his own country, and became intimately acquainted with all the leading branches of British industry; some of which—as the cotton and the woollen manufactures—he explained in the lecture-rooms of London, Manchester, and elsewhere; illustrating the various processes of carding, roving, spinning, weaving, &c., by the aid of working models prepared for the purpose. At a later period he extended his tours to the foreign capitals and manufacturing districts, and he never failed to bring home some archæological memoranda and sketches of mediæval domestic architecture, which served as materials for his subsequent publications. He introduced many valuable improvements into the manufacture of Globes, and in the projection of Maps. In the year 1830 he brought out a little volume entitled "A Familiar Introduction to the Science of Astronomy;" intended chiefly for the use of students in working problems on the globes. He also, in 1836, prepared a map of the heavens, in six sheets folio, which was edited by Sir John Lubbock, F.R.S. He took a very active and prominent part in the first movement for the amendment of the Patent Law, which however he eventually left to be accomplished by younger men.

During the last ten years of his life Mr. Newton gradually retired from public life, and resided chiefly at Herne Bay, where he, however, took much interest in local proceedings, in which he was very useful.

As a professional man he prosecuted with credit and success an active career, and in his family circle he was beloved and esteemed, and his decease, on the tenth of July, 1861, in his seventy-sixth year, was generally regretted.

He joined the Institution of Civil Engineers as an Associate in the year 1837; he was a very constant attendant at the meetings, and took an active part in the discussions.[1]

MR. JOHN PIGOTT SMITH was born in the year 1798; he was early articled to a Land Surveyor and Valuer, and in process of time set up in business on his own account. Other opportunities, however, offering, he for a time embarked in business, and prepared and published trigonometrical surveys of the parishes of Brighton, Birmingham, &c. Eventually he drove one of the fast coaches between London and Birmingham, in which position he had ample opportunity of studying, practically, the formation of good "Macadam" roads, a knowledge which he subsequently turned to account. At that period he made the acquaintance of the elder and the younger Stephenson, and was engaged by the former on surveys for Parliamentary Work. After some time he was elected the Surveyor for the town of Birmingham, and there he worked a great change in the character of the thoroughfares, for formerly even the footpaths were paved with round pebbles, familiarly styled 'petrified kidneys,' and the carriage ways were of the most uncomfortable kind. This state of things no longer exists, and there are now few towns where the thoroughfares are so well attended to as those of Birmingham. To attain this Mr. Pigott Smith devoted all his energies;—the system he introduced has been extensively copied in other places, and on this subject he contributed a Paper which was read at a meeting of the Institution of Civil Engineers[2] in 1854, and for which a Telford medal was awarded to him. His reputation as an authority in this branch of the profession was so high, that his advice was sought by the municipality of Paris when, after the popular tumults, during which paving stones were so freely used in the formation of barricades, it was determined to substitute the Macadam system as far as it was practicable, for the streets of the French capital.

In conjunction with the late Mr. John Roe (Assoc. Inst., C.E.), who was the consulting Engineer, Mr. Pigott Smith designed and partially executed a very complete system of sewerage for the town of Birmingham, and conjointly with Mr. Robert Rawlinson (Assoc. Inst. C.E.), he reported on the water supply for the Borough. His advice was also constantly sought for other towns, where improvements were required; in fact few men of the period were more generally, or more usefully employed, and it is to be regretted that repeated applications to the surviving friends and relatives of the late Mr. Smith have failed to extract from them the information for drawing up a Memoir which might have been made very interesting.

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[1] The following is a list of the principal works published by Mr. Newton:— "A Display of Heraldry," 8vo. Plate and cuts. London, 1846. "A Familiar Introduction to the Science of Astronomy." A Map and Memoir of "London in the Olden Time." "The London Journal of Arts and Sciences," 8vo. from 1820, and continued to the present time.

[2] *Vide* Minutes of Proceedings, Inst. C.E., vol. xiii. p. 221.

Mr. Pigott Smith was appointed Surveyor to the Commissioners of the Birmingham Improvement Acts in 1835, and on the vesting of their powers, together with those of the other parishes comprised within the borough, in the hands of the Town Council, in 1851, was appointed Borough Surveyor, which office he held until his retirement in 1857. He was much respected in his professional position, and his decease, which occurred at Manor House, Halford, Shipston-on-Stour, on the twenty-second of April, 1861, in his sixty-fourth year, caused great regret to a large circle of friends.

He joined the Institution of Civil Engineers as an Associate in the year 1851, and he always took much interest in the proceedings.

Mr. EDMUND TREHERNE joined the Institution in the year 1826, as an Associate, but having relinquished the profession for other pursuits he rarely attended the meetings; and repeated applications have failed to procure any materials for a memoir of him.

Mr. JOHN NEVILLE WARREN was born in London in May, 1818; he received his education first under a private tutor and subsequently at University College, London. He was articled to Mr. Francis Giles, (M. Inst. C.E.,) in 1836, and was actively engaged under him on various lines of railway in different parts of the kingdom. In 1841 he went to Hamburg and was engaged with Mr. W. Lindley, (M. Inst. C.E.,) in laying out lines of railway in the north of Germany. He received the thanks of the Senate of Hamburg, and a medal, for his services during the disastrous fire in that city in 1842, when he opened the line from Hamburg to Bergedorf, on his own responsibility, in order to convey the sufferers from the fire to a place of shelter and safety. On his return to England he was appointed, in 1844, Resident Engineer of the Guildford and Woking Railway, and when that line was completed, he remained for some years without any engagement in Engineering works, but during that interval he continued to take interest in scientific researches and in literature and the arts. At the close of 1854 he became connected with the Scinde Railway, being in fact one of the first persons who took an active part in it in this country. On the formation of the Company he became a Director, and in October, 1855, he went out to India as agent for the Company in Scinde, and from that time until his death, with the exception of five months in 1860, during which he came over to England for his private affairs, he remained incessantly occupied with the arduous duties of his post. The difficulties he had to contend against were neither few nor small, and the success which has attended the Company's operations is not a little due to the skill with which he managed its affairs. The commencement of the works was delayed by a difference of opinion between the Engineers of the Company and those of the Government as to the best direction for the line, and it was not till May, 1858, that the first sod was turned by Sir Bartle Frere, then Commissioner in Scinde. In June, 1859, the contractors became unable to carry on the works, and from that time their execution and completion devolved upon the officers of the Railway Company. The great amount of labour thus thrown on Mr. Warren at this time brought on an illness, from which however he recovered without being compelled to leave his post. The railway was opened for traffic in May, 1861, but during the summer of that year the line was on two occasions partially washed away by the rains, and the traffic was arrested. The incessant toil and anxiety caused by these occurrences, and the difficulty of starting the traffic on a new line with inexperienced hands, were so great, that Mr. Warren's health again gave way, and he was seized with acute inflammation of the liver in the latter end of August, 1861. His medical advisers were from the first apprehensive of a fatal result, aggravated, as such a disease always is, by a tropical climate. For some weeks he was unable to be moved, but an apparent diminution of the disease and the consequent relief from acute pain encouraged his friends to hope that if he could be conveyed to England he might recover. On the 8th of October, 1861, he was conveyed on board the steamer 'Tilly' from Kurrachee to Bombay, and seemed relieved by the three days' sea voyage between those ports. He was then transferred to the Peninsular and Oriental steamer 'Behar,' and soon afterwards became worse, and never rallied. He died in the Red Sea on the second day after passing Aden, on the 21st of October, 1861. The esteem in which he was held by all the officers of the Company in Scinde was very truly expressed by the Chief Engineer, in a Report which was annexed to that of the Directors to the Shareholders in March, 1862, in which he said, "I cannot close this Report without recording my sincere grief at the loss this Company has sustained in the death of Mr. J. Neville Warren. In this feeling I know every member of my staff participates. During the three and a half years in which I have held my present office, I can bear testimony to the untiring zeal and energy with which his very arduous duties were performed. And while the Company have in him lost a most valuable servant, I and all my staff mourn the loss of a kind friend, to whom we all looked up with affection and respect."

These sentiments were corroborated by Mr. W. P. Andrew, the Chairman of the Scinde Railway Company, who, in his Address to the Shareholders at the Annual General Meeting, March 28th, 1862, said, "He could not conclude without alluding to the great loss the Company had sustained since the last Meeting in consequence of the decease of their able and energetic agent, Mr. Neville Warren. From the earnest manner in which he discharged his duties, that gentleman had won the high commendation of Sir Bartle Frere, the Commissioner in Scinde, and in which His Excellency the Governor-General of India and his Council concurred. Considering that Mr. Warren had injured his health in his exertions to serve the Company, a resolution had been placed on the books appreciatory of his services, which would be read to the Meeting. The Directors had also gone further than that, and done what was perhaps beyond their strict duty, inasmuch as seeing that Mr. Warren's family had been left unprovided for, they had placed a sum of £500 in trust, with the sanction of the Secretary of State for India in Council, for the purpose of being appropriated to the education of his four children. He was gratified, to perceive, from the manner in which the Meeting had received the announcement, that they approved of the step which the Directors had taken. It was no doubt their duty to have consulted the proprietors before taking such a step, but Mr. Warren's death having occurred so soon after their last Meeting, they did not deem it necessary to again call them so soon together; and as the withholding any grant they were prepared to give, would have lost its grace and usefulness by having been withheld to the present time, the Directors had taken on themselves the responsibility of awarding it, and they now were gratified to find that in doing so they had the cordial sanction of the Shareholders."

Thus passed away a most promising man, whose energy and talent bid fair to lead him to an eminent position in the career he had embraced.

Mr. Warren joined the Institution as an Associate in the year 1849, and whenever his avocations allowed him, he was a constant attendant at the Meetings, and at all times took a great interest in the proceedings.

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